Cognitive Flexibility in Integrated Task Sets
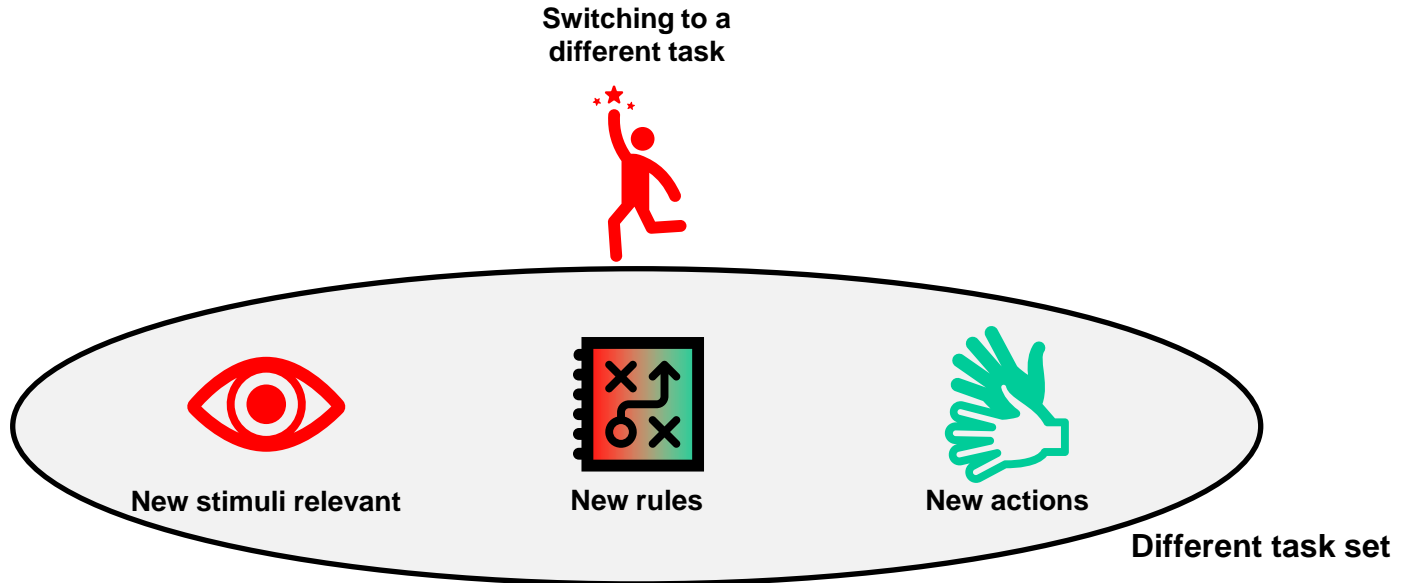
How to perform a task? How to switch to another task?
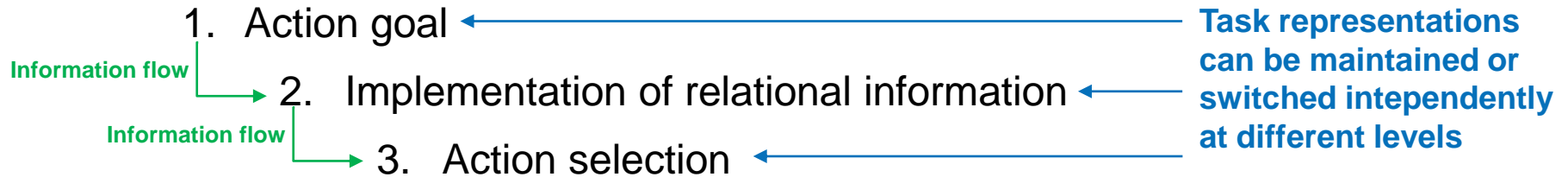
Succesful task performance

Stimulus selection

Rule application

Action selection

Task set

How to perform a task? How to switch to another task?

Switching to a
different task

New stimuli relevant

New rules

New actions

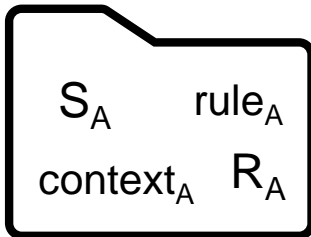Different task set
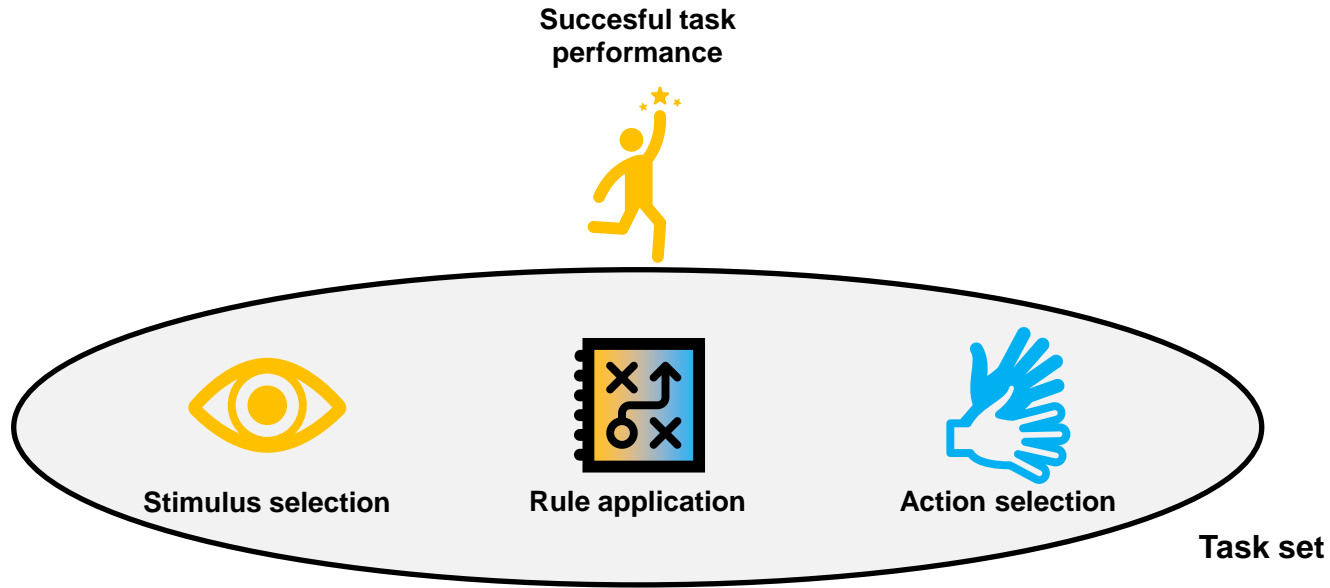
Traditional hierarchical models of control

- Cognitive control (and its underlying neural components) is represented hierarchically:

  More abstract control representations → Higher hierarchical level

- Lower levels inherit information from higher levels

1. Action goal ← **Task representations can be maintained or switched intependently at different levels**

Information flow →

   2. Implementation of relational information ←

Information flow →

    3. Action selection ←

(e.g., Badre, 2008; Schneider et al. 2006)

# BRAC inspired perspectives on task sets

- Features of different abstractional levels are bound into an integrated representation (event file).

- (Un-)binding effects can occur as the result of non-abstract feature repetitions.

S_A $rule_A$
$context_A$ R_A

(e.g., Schiltenwolf et al., 2024; Benini et al., 2022; Mayr & Bryck, 2005; Kikomoto & Mayr, 2020)

BRAC inspired perspectives on task sets

- Features of different abstractional levels are bound into an integrated representation (event file).

- (Un-)binding effects can occur as the result of non-abstract feature repetitions.

→ Strict hierarchical information flow seems unlikely

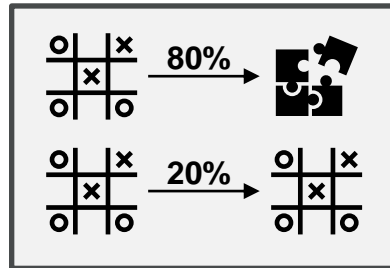(e.g., Schiltenwolf et al., 2024; Benini et al., 2022; Mayr & Bryck, 2005; Kikomoto & Mayr, 2020)
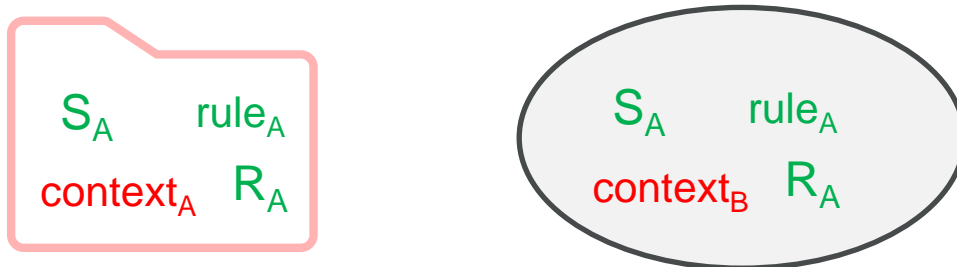
Cognitive Flexibility

- The cognitive system cannot only adopt new control states.

- It can also adjust the flexibility of control adaptations.

Between-task flexibility

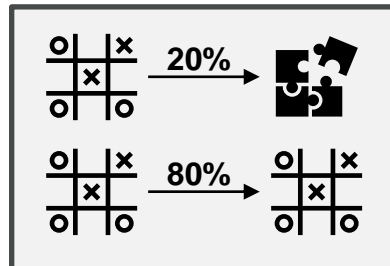- Increased demands of task flexibility reduce costs of task switching

High switch demands

Easier to switch tasks
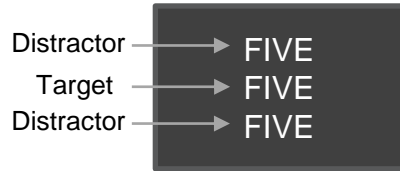
Harder to repeat tasks

Low switch demands

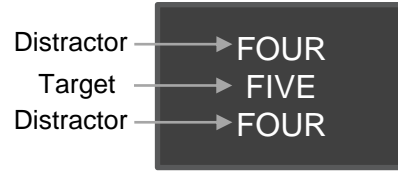Harder to switch tasks

Easier to repeat tasks

(e.g., Siqi-Liu & Egner, 2020, 2023; Dreisbach & Haider, 2006)

Within-task flexibility

• Conflict tasks: Varying attentional demands, same task.

Distractor → FIVE
Target → FIVE
Distractor → FIVE

Congruent trial
Helpful distractors

Distractor → FOUR
Target → FIVE
Distractor → FOUR
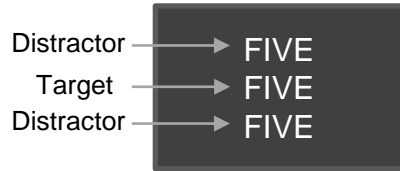
Incongruent trial
Misleading distractors

Distractor influence indexed by
Congruency Effect = Inc-Con

Within-task flexibility
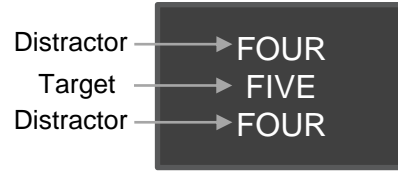
- Conflict tasks: Varying attentional demands, same task

Congruent trial
Helpful distractors

Incongruent trial
Misleading distractors

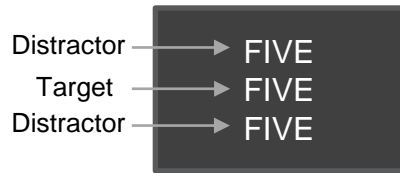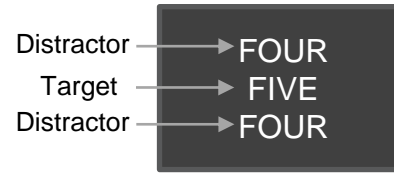Distractor influence indexed by
Congruency Effect = Inc-Con

- Attentional control varies as a function of task demands.

- Congruency sequence effect (CSE) – a measure of control flexibility
$$CSE = (INC - CON)_{N-1\ con} - (INC - CON)_{N-1\ inc}$$

Within-task flexibility

- Conflict tasks: Varying attentional demands, same task

Distractor →	FIVE
Target →	FIVE
Distractor →	FIVE

Congruent trial
Helpful distractors

Distractor →	FOUR
Target →	FIVE
Distractor →	FOUR

Incongruent trial
Misleading distractors

Distractor influence indexed by
Congruency Effect = Inc-Con

- Attentional control varies as a function of task demands.

- Congruency sequence effect (CSE) – a measure of control flexibility.
  CSE = (INC – CON)$_{N-1\ con}$ – (INC – CON)$_{N-1\ inc}$

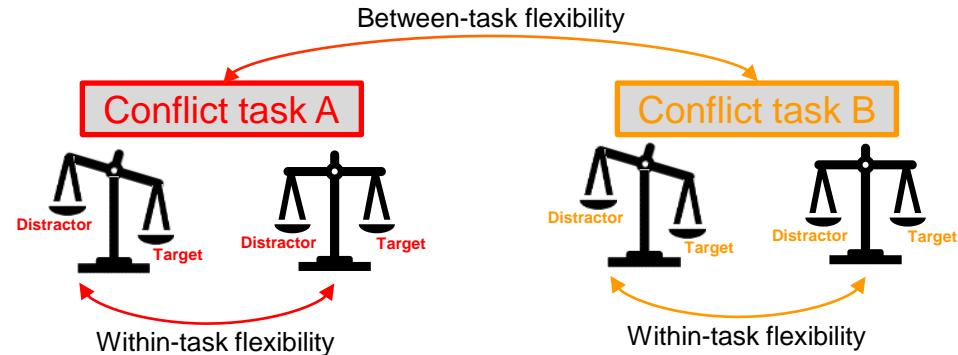Large CSE: Easy to adopt in N-1 a control state
Small CSE: Hard to adopt in N-1 a control state
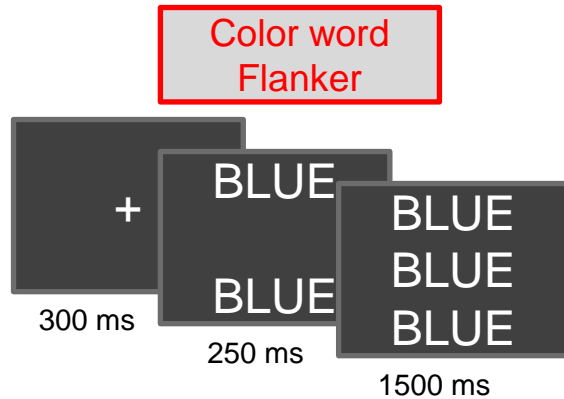that is measured in the current trial.

Interplay of between- and within-task flexibility

- Do demands of between-task flexibility affect within-task flexibility?

- Hierarchical task control models suggest that control adjustments on different levels are employed independently.

- BRAC perspectives highlight the necessity of integrated task representations (across „hierarchical levels")
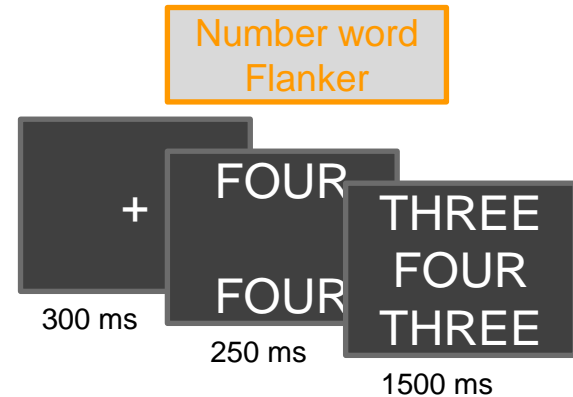

Between-task flexibility

Conflict task A   Conflict task B

Distractor   Distractor   Target   Distractor   Distractor   Target
              Target   Target

Within-task flexibility   Within-task flexibility

Methods

Methods

Single task block A	Single task block B	5x	Dual task blocks	Single task block A	Single task block B

No between-task flexibility demands

Demands of task switching

No between-task flexibility demands
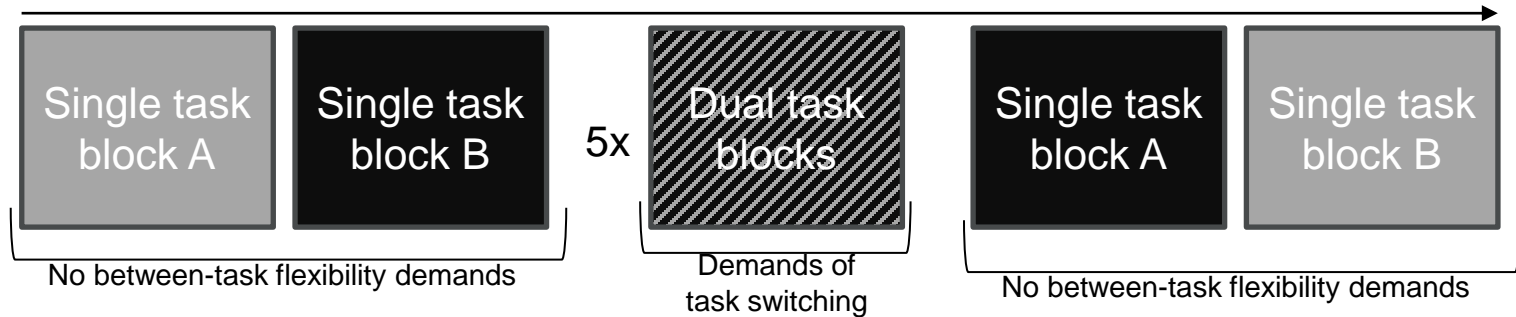
- Measure within-task flexibility in Single and Dual task blocks (CSE)

Methods

Methods

Single task block A	Single task block B	5x	Dual task blocks	Single task block A	Single task block B

No between-task flexibility demands   Demands of task switching   No between-task flexibility demands
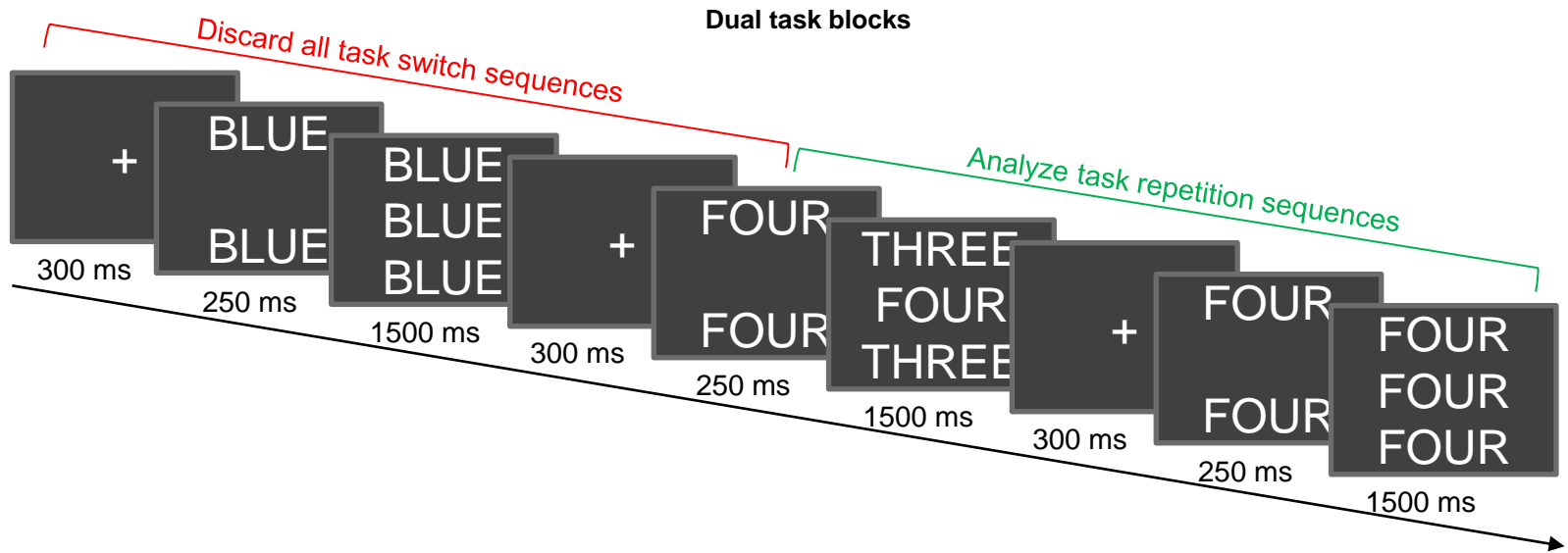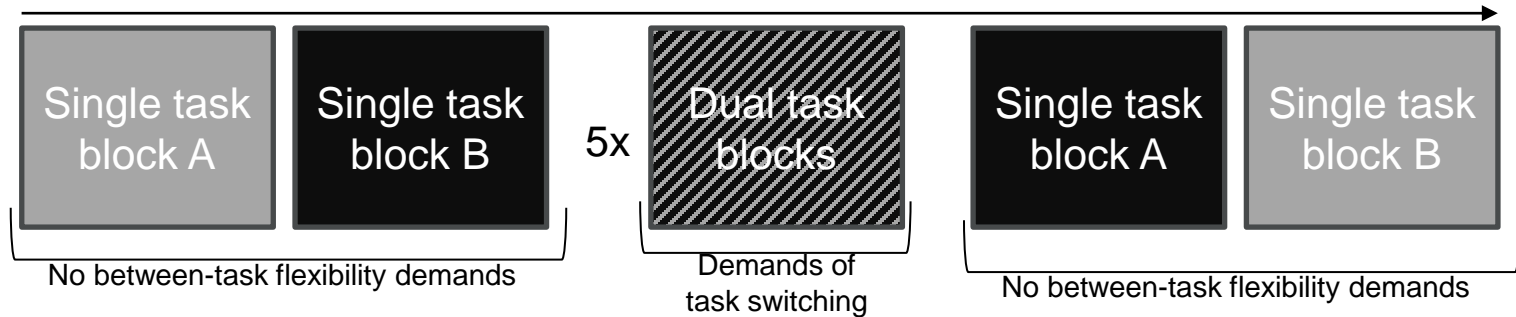
- Measure within-task flexibility in Single and Dual task blocks (CSE)

- If between-task flexibility demands affect within-task flexibility,
  CSEs should be larger in the *Dual task blocks* than in the *Single task blocks.*

Results

Exp 1a
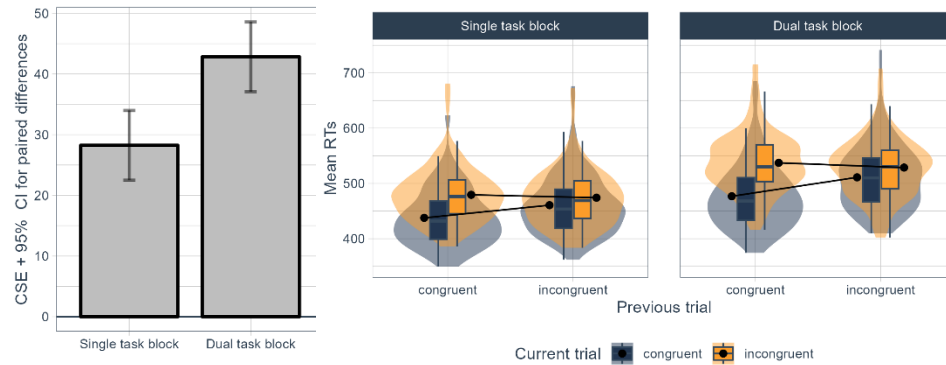
S-R repetitions allowed

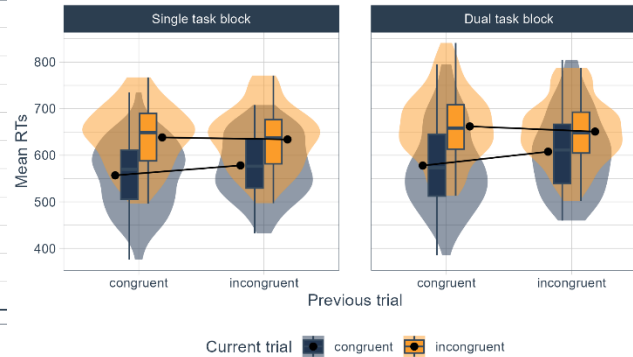✓ Dual task CSE > Single task CSE

Results

Exp 1a

Exp 1b

S-R repetitions allowed
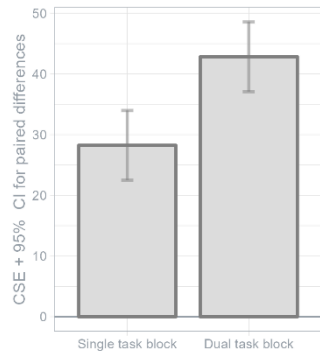
No S-R repetitions

✓ Dual task CSE > Single task CSE
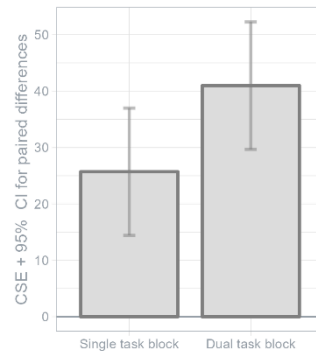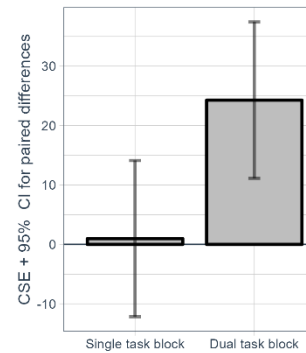
Results

Exp 1a

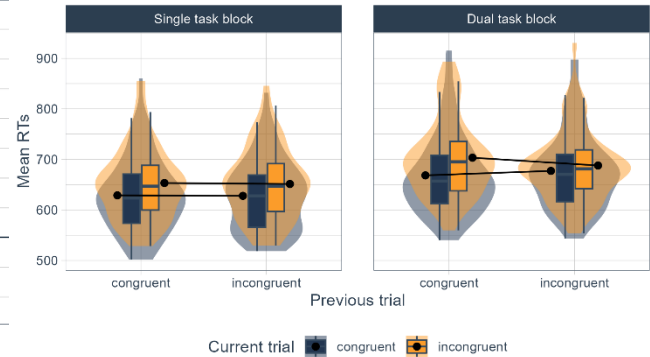S-R repetitions allowed

Exp 1b

No S-R repetitions

Exp 1c

Simultaneous target and distractor onset

✓ Dual task CSE > Single task CSE

# Structural similarity as flexibility boundary?

- In Exp. 1a, 1b, and 1c, the two conflict tasks were structurally identical.

- CSEs across tasks indicate that performance in both task relied on shared control representations.

→ Can we replicate the results in conflict tasks where CSEs arise from different control mechanisms?
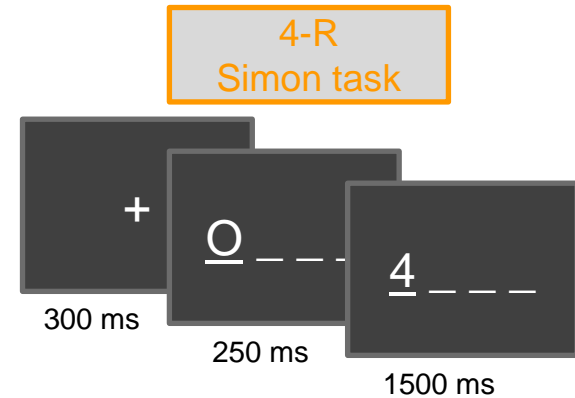
Methods Exp. 2

Flanker task

A
A

+

A
D
A

300 ms

250 ms

1500 ms
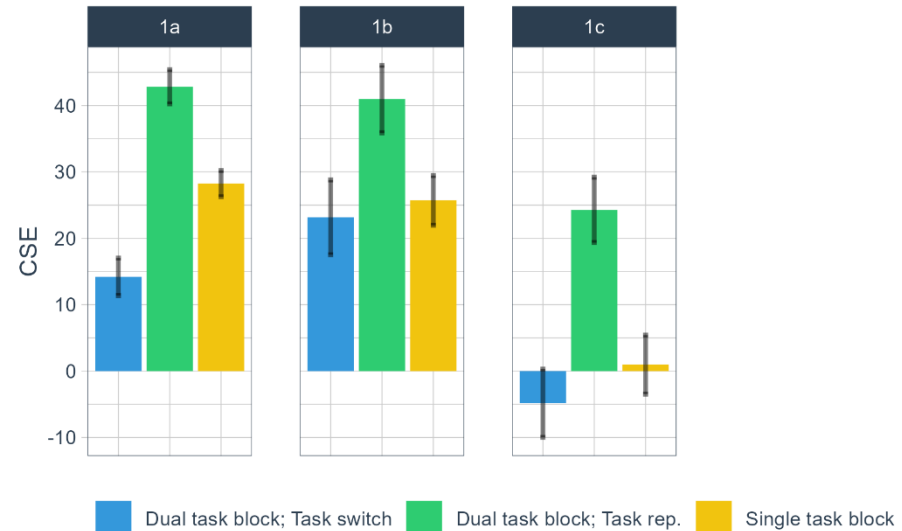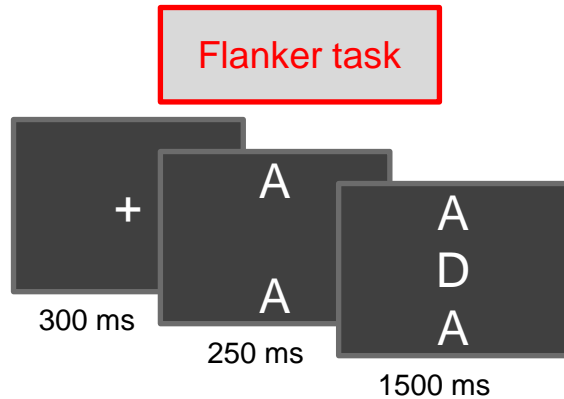
S-R mapping:
- A → right index finger
- B → right middle finger
- C → right ring finger
- D → right little finger

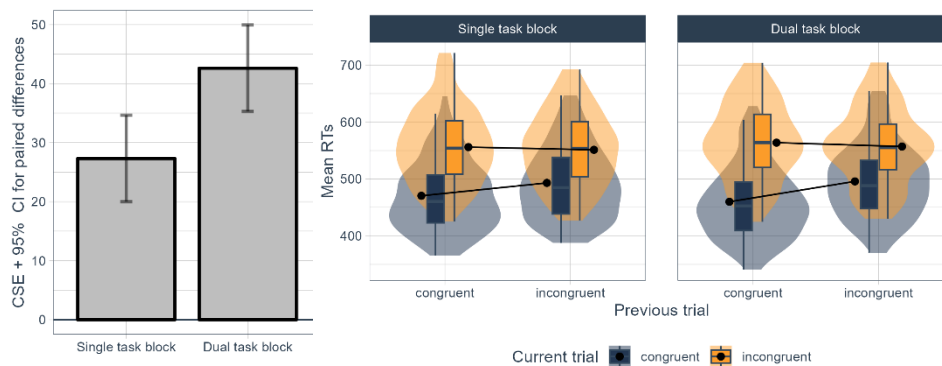4-R
Simon task

+

O _ _ _

4 _ _ _

300 ms

250 ms

1500 ms

S-R mapping:
- 1 → right index finger
- 2 → right middle finger
- 3 → right ring finger
- 4 → right little finger

Results Exp 2

Flanker<->Simon task

✓ Dual task CSE > Single task CSE

Summary

- In four experiments, within-task control flexibility (CSE) was larger in conditions of between-task flexibility demands (dual task blocks) than without between-task flexibility demands (single task blocks).

- Results suggest that cognitive flexibility generalizes across „hierarchical levels".

- In line with BRAC inspired perspective of integrated task representations.

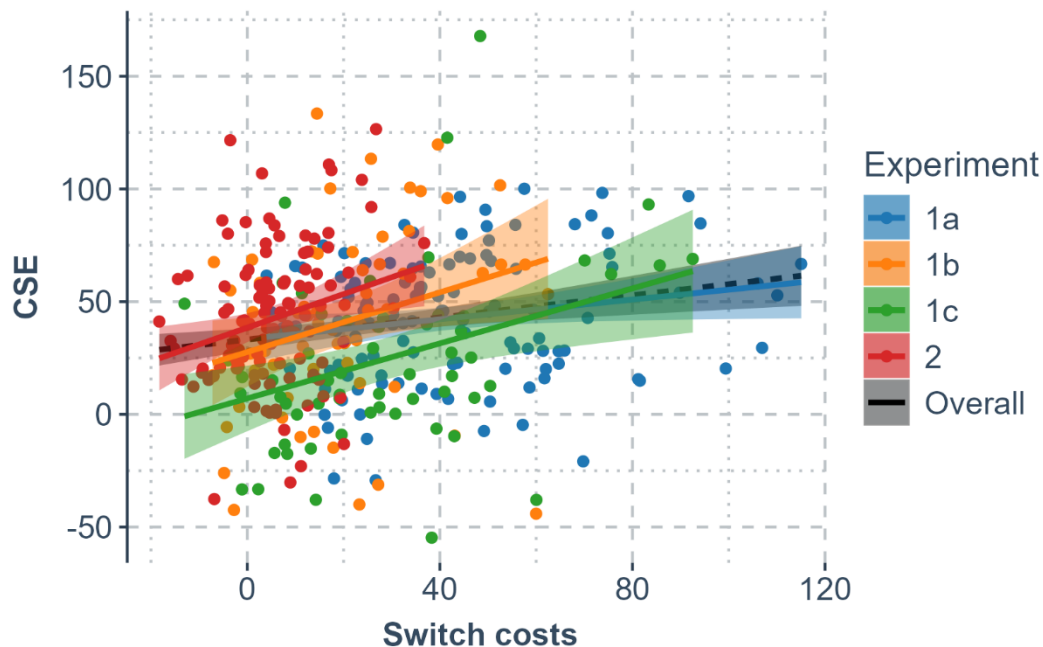→ More BRAC perspectives on cognitive flexibility / meta control?

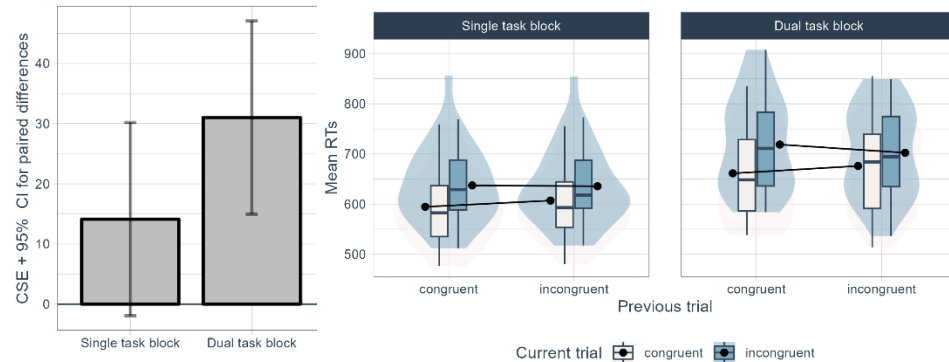# Effects are not driven by larger conflict in dual task blocks
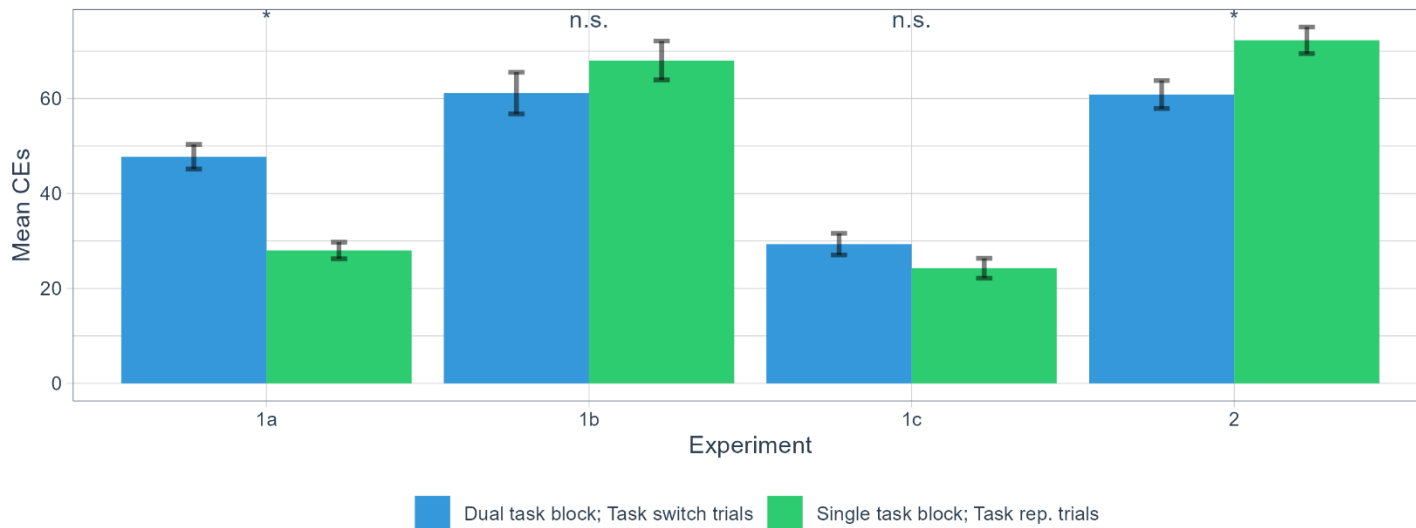
Switch costs correlate with task rep. CSE in dual task blocks

Reanalysis of Straub et al. (2024)

- 2 versions of face stroop (gender vs. emotion detection)

✓ Dual task CSE > Single task CSE

Results in error rates