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Evidence accumulation modeling for the Detection Response Task when combined with the Box Task

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Secondary task demand while driving

- Drivers often shift their attention to **non-driving related secondary tasks**
  (Huemer et al., 2018; Kubitzki and Fastenmeier, 2016)
  → High potential for accidents (Carney et al., 2015)
- **Estimation of distraction potential** of in-vehicle systems (early in the development process)
- Modern in-vehicle systems are designed for **multimodal interaction** (Strayer, 2015)
  → **Visual-manual** and **cognitive** task demand
- **Lack of methods** that can distinguish accurately between *different* secondary task demands
  (Engström & Markkula , 2007; Morgenstern et al., 2020a)

Box Task & Detection Response Task

- Box Task in combination with a Detection Response Task (BT + DRT, Hsieh & Seaman, n. d.)
  - **Easy-to-use** method for **differentiated** assessment of secondary task demand
  - Foundation: **Dimensional Model of Driver Demand** (Young et al., 2016)

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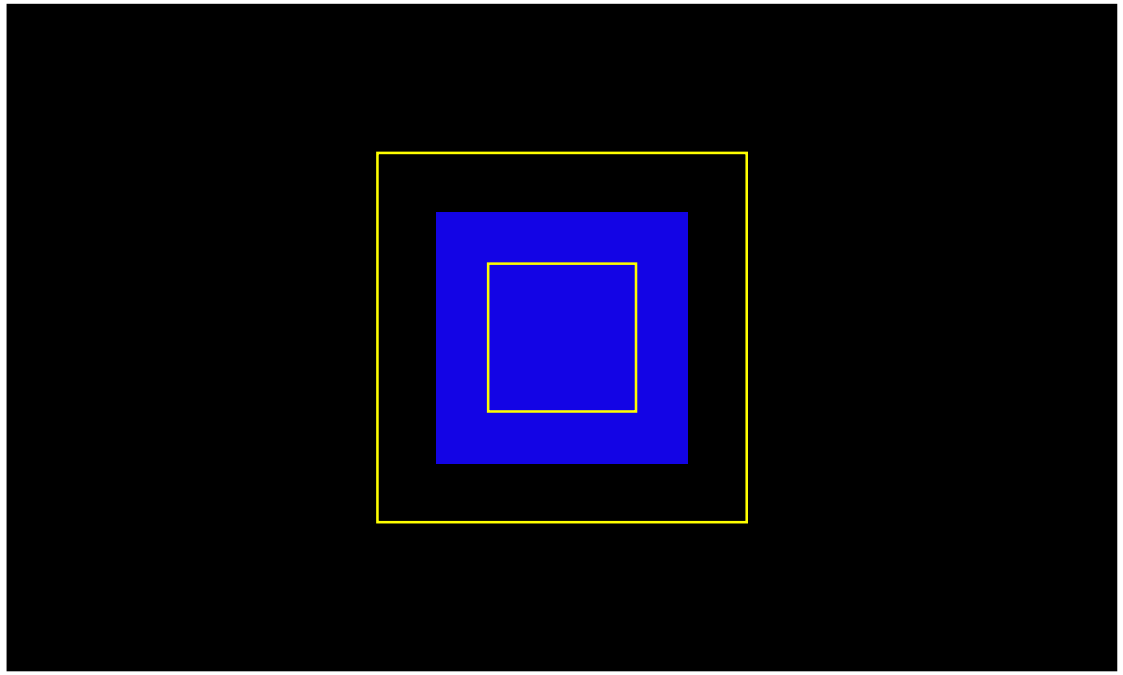
Physical (visual-manual) demand

- Associated with **lateral & longitudinal vehicle control**
- Assessed using the **BT**
  - Simulation of a car-following scenario
  - Dynamic blue box changes its lateral position (~ lane keeping) and its size (~ headway)
  - Participants have to use a steering wheel and a gas pedal to adjust the box position and size



(Trommler et al., 2020)

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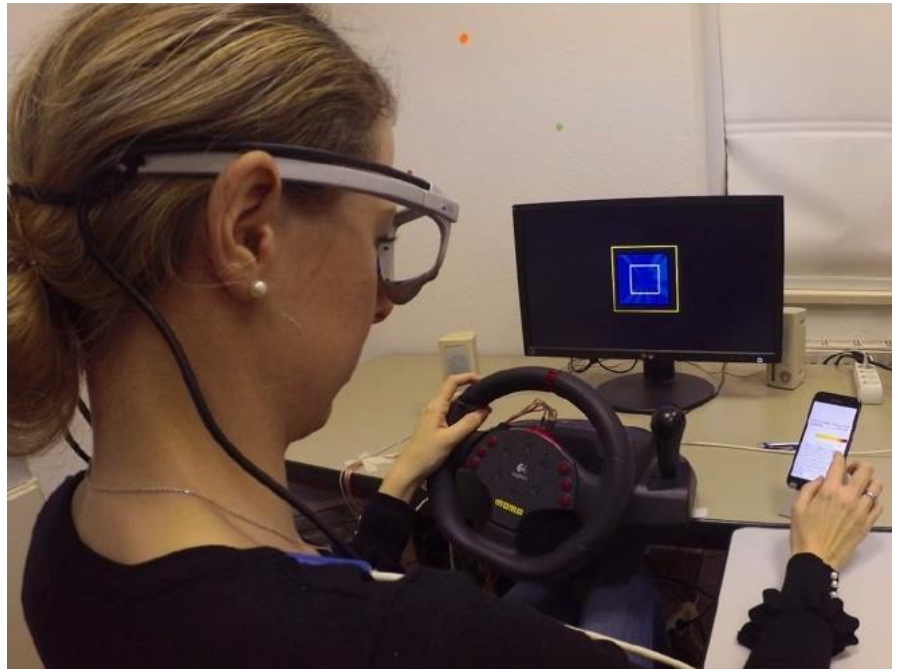

(Morgenstern et al., 2020a)

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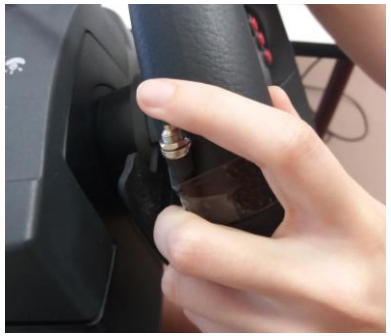
Cognitive demand

- Associated with **event detection**
- Assessed using the **DRT**
  - Tactile DRT according to the ISO standard (see ISO 17488, 2016)



Controlled and automatic task performance

Controlled task performance: Novel, non-routine, difficult tasks

- **Less consistent** (i.e., variable, uncertain) mapping between stimuli and responses
- Executive cognitive skills (e.g., working memory) and thus **attentional effort is required** ("Cognitive Control", "Supervisory Attentional System")

Automatic task performance: Practiced tasks

- **Learned** association between stimuli and responses through **repeated exposure** and **consistency**
- **Effortless**, generally unconscious task performance with **less cognitive control**

(Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977; Norman & Shallice, 1986; Engström et al., 2017)

Controlled and automatic processing while performing the BT & DRT

- **Start of an experimental session:** BT & DRT = unfamiliar and less practiced task
  - Task performance requires cognitive control
  - BT + (very) difficult cognitive tasks → Higher variability in box position

- **However:** BT & DRT include a highly consistent mapping between stimuli and responses
  - BT: Error correction in box position and box size
  - DRT: Response to tactile stimulus

Is there a **transition** from **controlled to automatic** processing
while performing the BT & DRT?
Is there a **decrease of cognitive control** with effects on the **performance parameters**?

→ Implications on recommendations regarding the **duration of practicing** the BT & DRT
before an experimental session.

Evidence accumulation modeling for the DRT

- Mathematical models which describe perceptual decision-making or **stimulus detection** as an **noisy accumulation** of stimulus information (**evidence**) from a **starting point** to a **response threshold**

- A **response** to a stimulus is initiated when the amount of accumulated evidence **reaches the threshold**

- Decomposition of behavioral data (i.e., reaction times and response accuracies) into **components of the cognitive information processing**

(Ratcliff & Van Dongen, 2011; Heathcote, 2004; Matzke et al., 2017a; Matzke et al., 2017b)

Evidence accumulation modeling for the DRT

Key parameter of evidence accumulation models:

- Rate of evidence accumulation (~ Speed of information processing)
- Response threshold (~ Response accuracy and caution)
- Non-decision time (~ Time for stimulus encoding and motor execution)
- Omission parameter for missing responses (~ Failures in stimulus encoding or evidence accumulation)

Evidence accumulation modeling was previously **used for the DRT** (e.g., Tillman et al., 2017; Castro et al., 2019)

- Cognitive load associated with:
  - Lower rate of evidence accumulation
  - Higher response threshold
  - Faster non-decision time
  - Higher response omission parameter

Evidence accumulation modeling for the DRT

Aim of this analysis:

- Replication of existing effects regarding the cognitive load for the DRT when combined with the BT
- Analysis of changes (especially in the rate) of evidence accumulation for the DRT when combined with the BT during an experimental session

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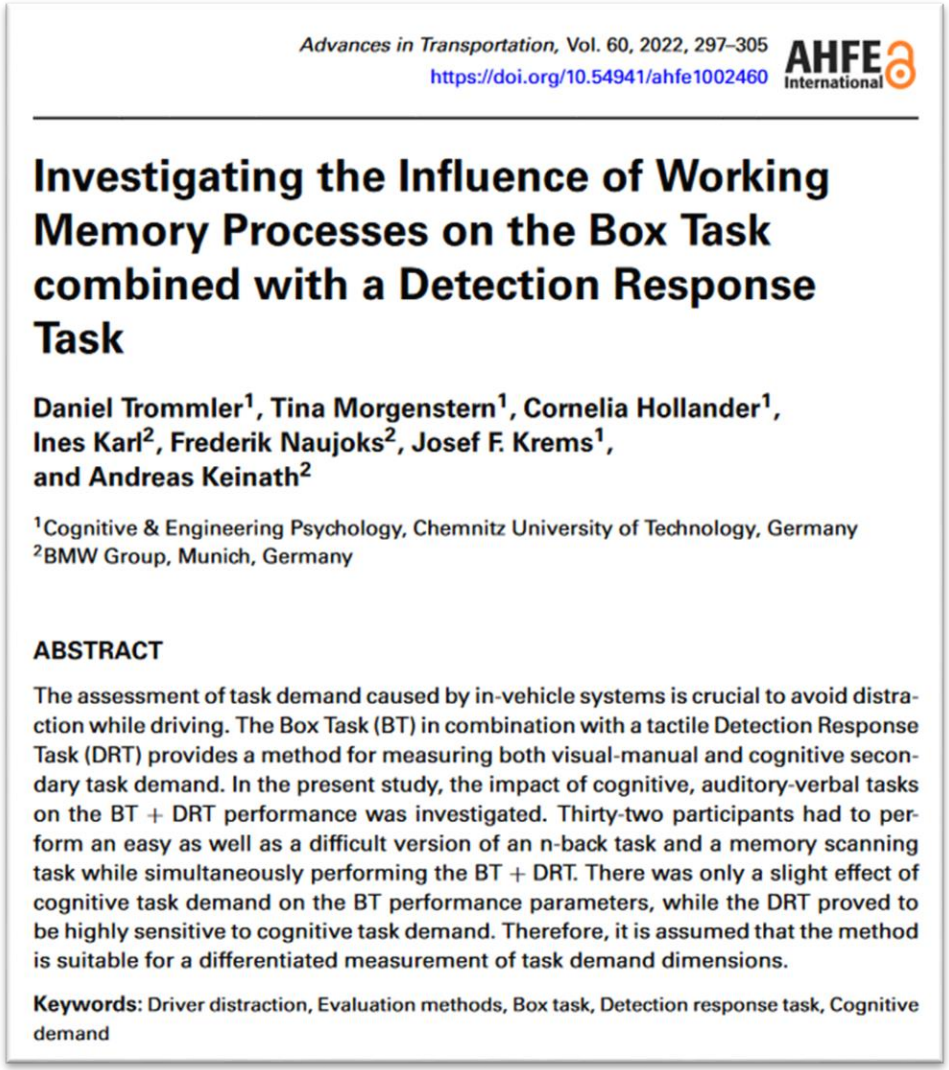

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Investigating the Influence of Working Memory Processes on the Box Task combined with a Detection Response Task

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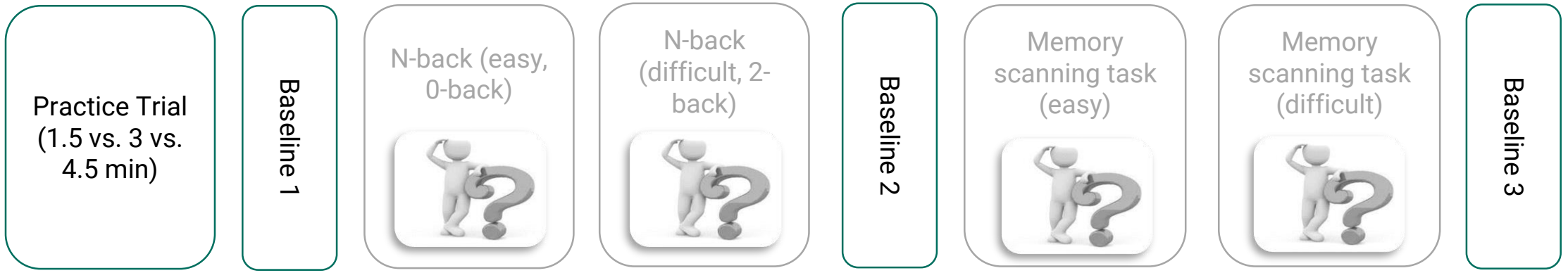
ABSTRACT

The assessment of task demand caused by in-vehicle systems is crucial to avoid distraction while driving. The Box Task (BT) in combination with a tactile Detection Response Task (DRT) provides a method for measuring both visual-manual and cognitive secondary task demand. In the present study, the impact of cognitive, auditory-verbal tasks on the BT + DRT performance was investigated. Thirty-two participants had to perform an easy as well as a difficult version of an n-back task and a memory scanning task while simultaneously performing the BT + DRT. There was only a slight effect of cognitive task demand on the BT performance parameters, while the DRT proved to be highly sensitive to cognitive task demand. Therefore, it is assumed that the method is suitable for a differentiated measurement of task demand dimensions.

Keywords: Driver distraction, Evaluation methods, Box task, Detection response task, Cognitive demand

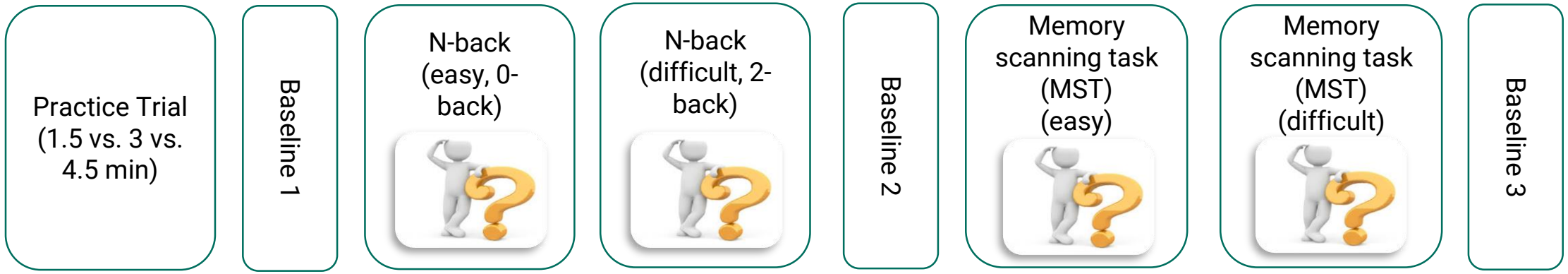
Method: Procedure

- Initial practice trial
- 3 Baseline drives (without secondary task engagement)

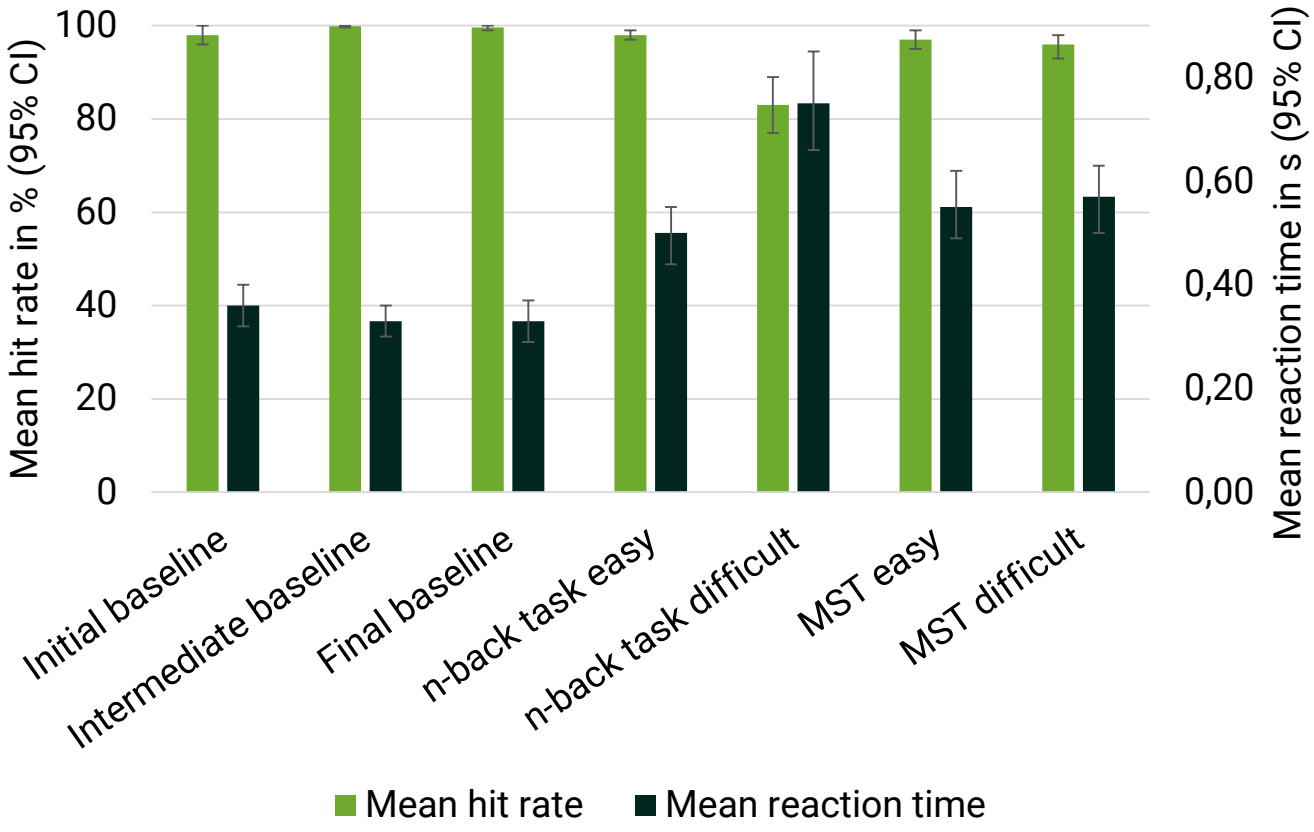


Method: Procedure

- Initial practice trial
- 3 Baseline drives (without secondary task engagement)
- Two test blocks
  1. Written instruction on the secondary task with practice trial
  2. Dual-task conditions with easy and difficult cognitive tasks



Results: DRT performance



Hit rate

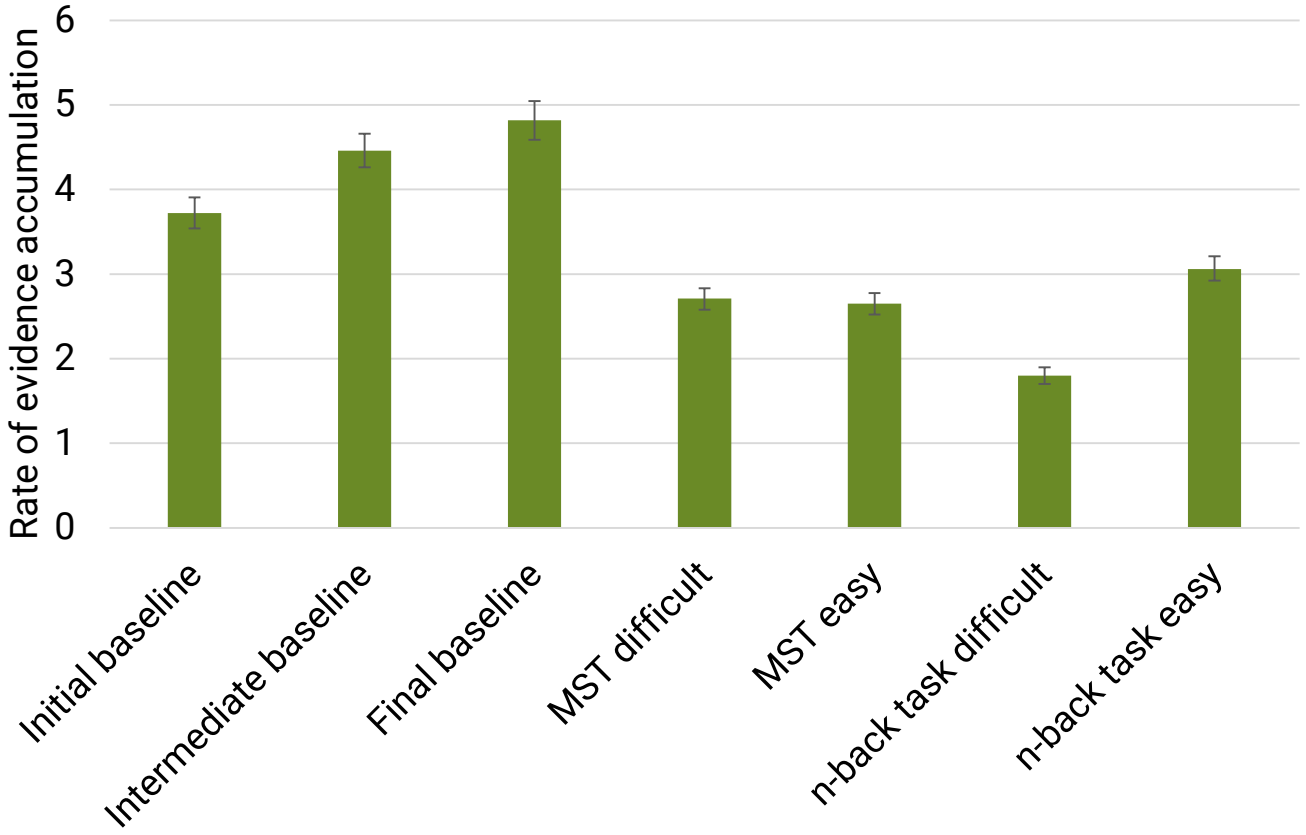
- **Significant difference** across task conditions (χ^2 (6) = 86.77, p < .001, W = .47)
- Significant differences between the **baseline drives** and the **dual-task conditions** (except for initial baseline drive and easy MST)
- The **difficult n-back task** differed significantly from the easy n-back task as well as the easy and difficult MST

Reaction time

- **Significant difference** across task conditions (χ^2 (6) = 154.18, p < .001, W = .83)
- All **baseline drives** differed significantly from the **dual-task conditions**
- The **difficult n-back task** differed significantly from the easy n-back task as well as the easy and difficult MST

Results: Rate of evidence accumulation

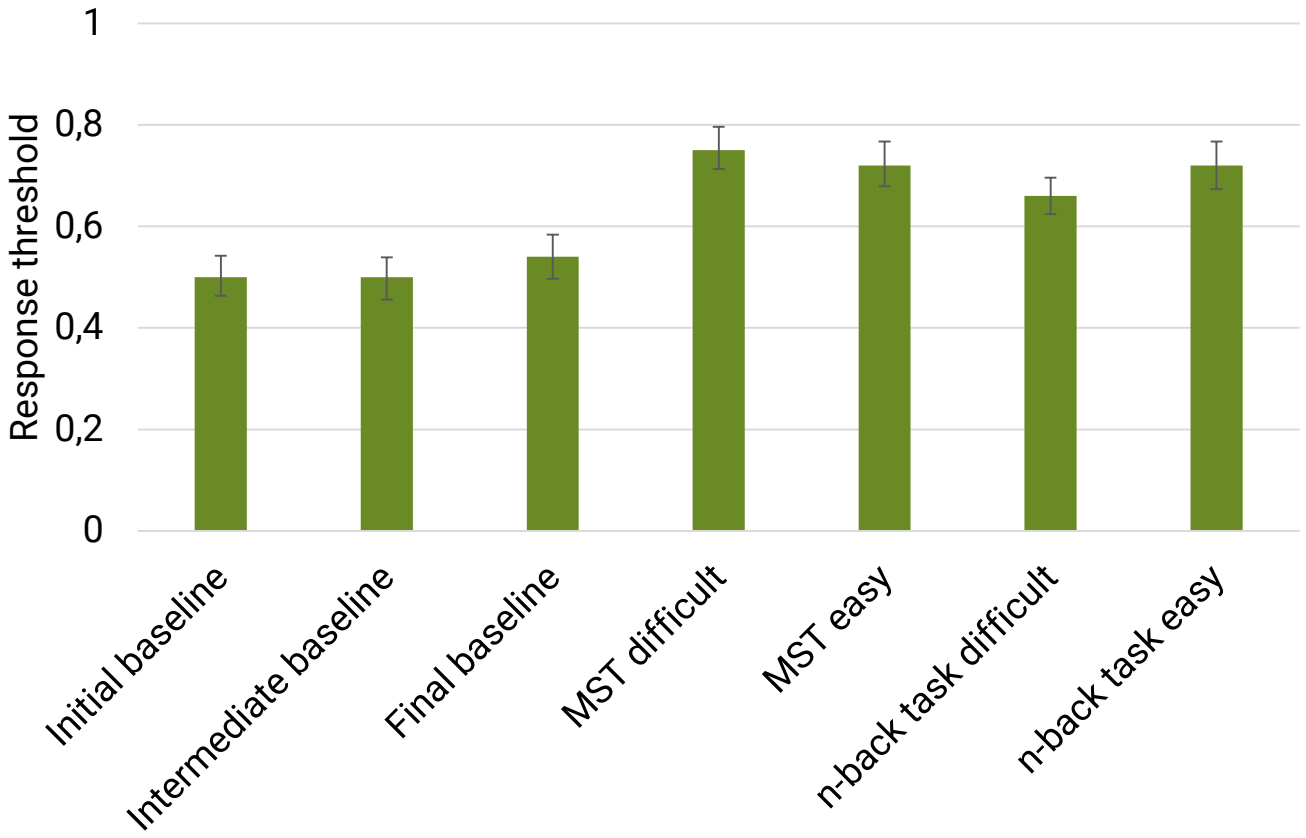
(~ Speed of information processing)



- **Significantly lower rate** for all **dual-task** conditions compared to **baseline** conditions (all $p < .001$)
- All **dual-task conditions differed** significantly from **each other** (all $p < .001$), except for the easy and the difficult MST
- **Significantly higher rate** between the **initial** and **intermediate baseline** conditions ($p < .001$) and between the **intermediate** and **final baseline** conditions ($p = .009$)

Results: Response threshold

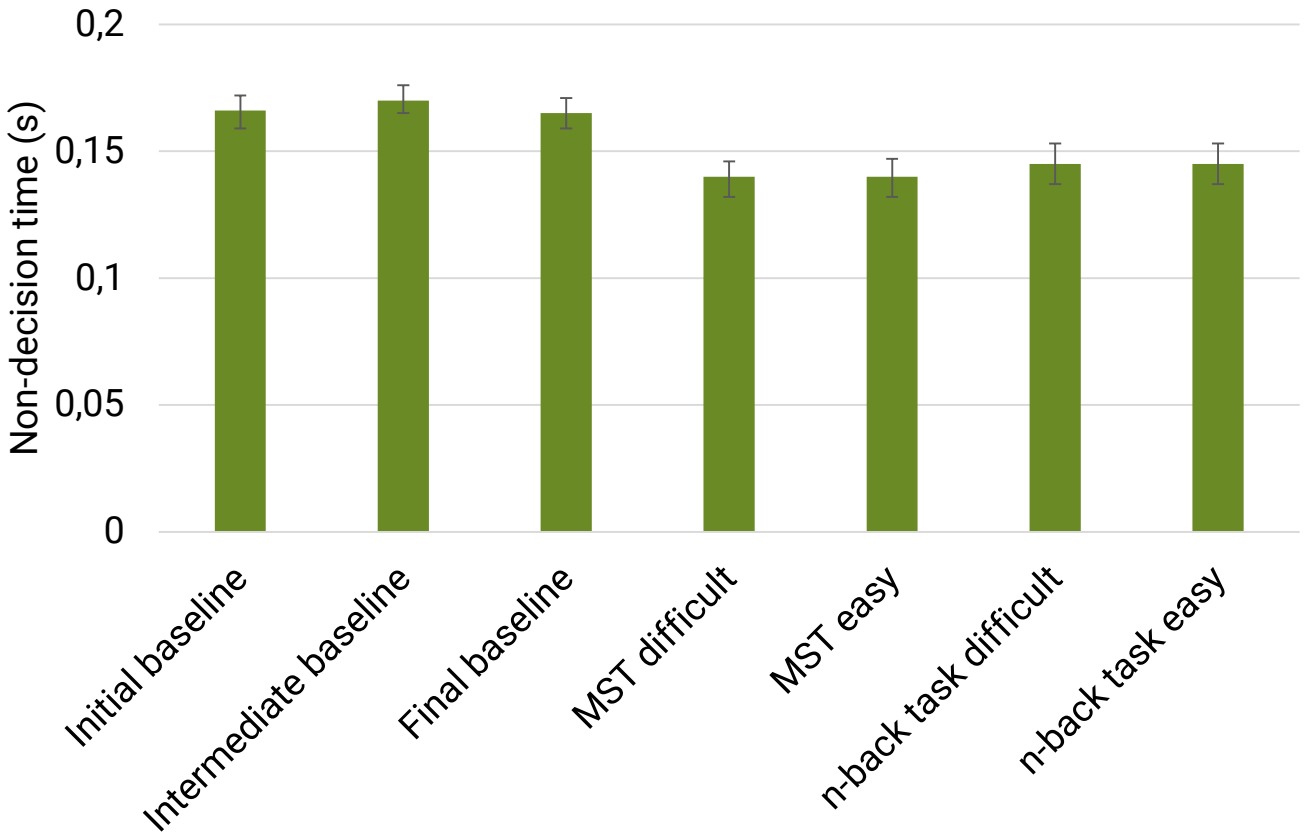
(~ Response caution)



- **Significantly higher response threshold** in the **dual-task** conditions compared to all **baseline** conditions (all $p < .001$)
- Response threshold was almost **constant for all dual-task conditions**, except for a significantly lower response threshold in the difficult n-back task
  (for the difficult n-back task and the easy n-back task: $p = .021$)
- **No significant differences** between the **baseline conditions**

Results: Non-decision time

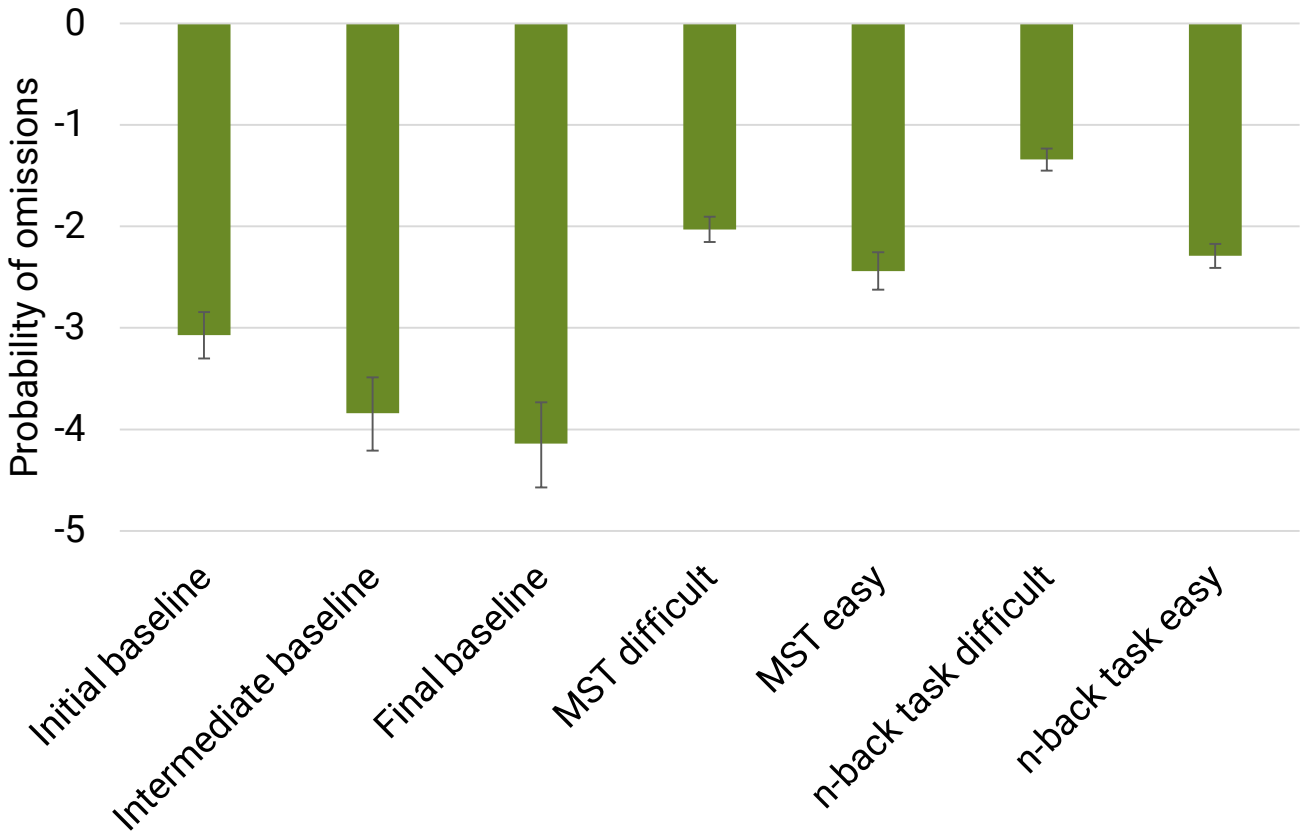
(~ Time for stimulus encoding and motor execution)



- **Significant difference** between **baseline** and **dual-task conditions**
- **Faster encoding and motor execution processes** in the presence of **cognitive load** (all $p < .001$)
- **No significant differences** between the **baseline conditions**

Results: Omission parameter

(~ Failures in stimulus encoding or evidence accumulation)



- **Significant differences between all dual-task conditions**, except for the easy MST and the easy n-back task
  (for difficult MST and easy n-back task: $p = .002$; all other $p < .001$)
- **Significant difference** between **initial** and **intermediate baseline** condition ($p < .001$)
- **Significant higher probability of omissions** in presence of **cognitive load**

Conclusion & further work

- **Previous findings** regarding the effects of cognitive load on DRT **were confirmed**
  - Lower rate of evidence accumulation, higher response threshold and faster non-decision time
- **Transition from controlled to automatic task performance** during the experimental session is **possible**
  - Increase in the rate of evidence accumulation for the DRT when combined with the BT across the three baseline conditions → adequate duration of practicing is necessary
  - Consistent mapping between stimuli and responses could lead to a decrease of cognitive control while performing the BT & DRT
- **Further analysis:**
  - Is the increase in the rate of evidence accumulation associated with (practical relevant) differences in the performance measures of the BT (e.g., variability of box position)?
  - Are there differences in the rate of evidence accumulation depending on the different durations of practicing?

THANK YOU FOR YOUR ATTENTION!