Differential Effects of Working Memory Load During Motor Decision-Making on Planning and Execution of Goal-Directed Pointing Movements

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Background

In everyday life, individuals have to regularly decide upon one out of multiple potential motor actions to be performed, necessitating the integration of perceptual, cognitive, and motor processes (Cisek, 2007; Cisek & Kalaska, 2010; van Ede & Nobre, 2023). Action-related decision processes can be probed in real-time by analyzing kinematics of movement trajectories (Gallivan & Chapman, 2014; Gallivan et al., 2018).

Working memory (WM) serves to inform potential and sequential upcoming behavior (van Ede & Nobre, 2023). However, the influence of cognitive, i.e. working memory load during decision-making on subsequent motor action execution, remains largely unexplored, yet (Gordon et al., 2021).

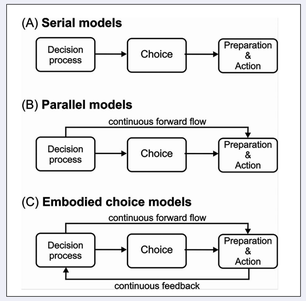

Fig. 1: Schematic presentation of potential links between decision and action in action-related decision making (Lepora & Pezzulo, 2015, p. 3)

Study aim:

This study investigated the influence of working memory load during motor decision making on goal-directed pointing movements, hypothesizing that increased WM load affects decision performance and leads to delays in action selection, potentially altering movement execution.

Statistical analysis:

- Repeated-measures ANOVA were calculated for decision performance and decision efficiency
- Linear mixed model ANOVAs were calculated for all other parameters with random slope and random intercept for subject and random intercept by-target

Conclusion

Cognitive load during motor decision-making influences action selection in goal-directed pointing movements. However, cognitive load did not affect movement execution, suggesting action specification to be unaffected by working memory load. Future research should focus on specifying task and environmental conditions under which embodied choices occur and try to identify related (neuro-)physiological markers.

Methods

Participants: n = 43, 24 female, age: 25.6 ± 3.7 years (mean ± SD, range: 20 – 37 years)
Task: n-back task (see Fig. 2)
Conditions: 1- / 2- / 3-back condition
Trials: 4 blocks x 15 trials per condition

Parameters:

- Action selection:
  - Decision performance (Accuracy rate in %)
  - Reaction time (ms)
  - Decision efficiency (i.e. speed-accuracy trade-off, Inverse efficiency score)
- Action specification:
  - Deviation of fingertip trajectory from straight line (Index of Curvature in %)
  - Movement time (s)
  - Peak velocity (m/s)

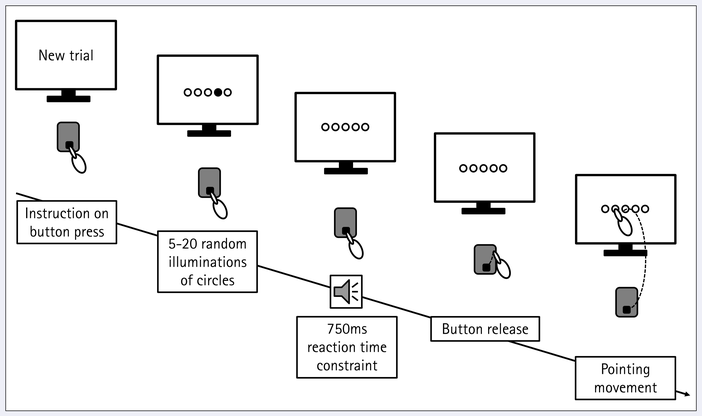

Fig. 2. Task procedure. Participants observed five circular targets randomly illuminating on a computer screen. Following an auditory start signal, they had to point towards the target which was illuminated n-steps back under a reaction time constraint. Movement kinematics were assessed using an optical motion tracking system (Qualisys).

Results

Action selection

- Decision performance deteriorates under high WM load ($F(1.10,46.11) = 144.8$, $p < .001$, $\eta_p^2 = 0.78$; Fig. 3A)
- Slower reaction times with higher WM load ($F(2,41.78) = 18.51$, $p < .001$; Fig. 3B)
- Efficiency decreases under high WM load ($F(1.16,48.59) = 61.32$, $p < .001$, $\eta_p^2 = 0.59$; Fig. 3C)

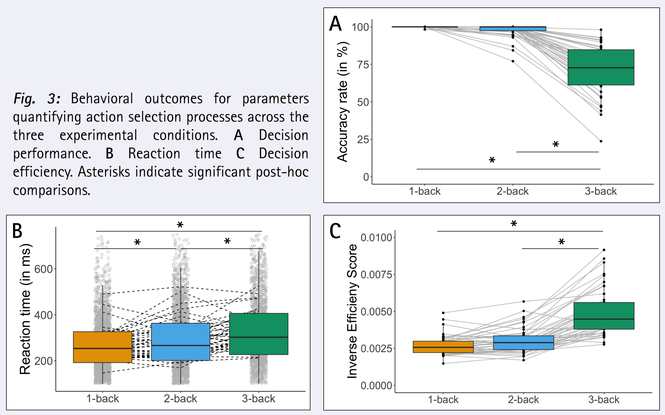

Fig. 3: Behavioral outcomes for parameters quantifying action selection processes across the three experimental conditions. **A** Decision performance. **B** Reaction time **C** Decision efficiency. Asterisks indicate significant post-hoc comparisons.

Action specification

- Qualitatively similar trajectories for all WM load conditions (Fig. 4A)
- Curvature of trajectories does not change under changing WM load ($\chi^2(2) = 3.88$, $p = .09$; Fig. 4B)
- WM load does not affect movement time ($F(2,41.86) = 2.72$, $p = 0.08$; Fig. 4C)
- WM load does not affect peak velocity ($F(2,41.83) = 1.16$, $p = 0.32$; Fig. 4D)

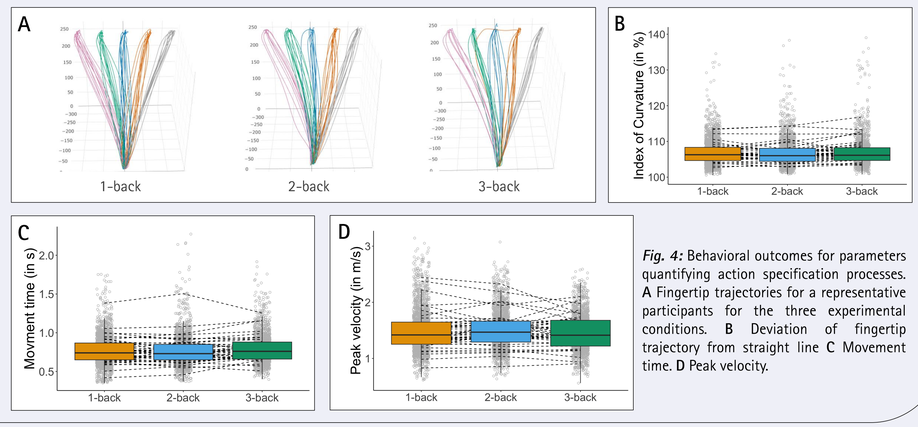

Fig. 4: Behavioral outcomes for parameters quantifying action specification processes. **A** Fingertip trajectories for a representative participants for the three experimental conditions. **B** Deviation of fingertip trajectory from straight line **C** Movement time. **D** Peak velocity.

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