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Problem Solving in the Human-Machine-Interaction: Rethinking the Role of Spatial Working Memory

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Introduction

Motivation: When analysing problem solving behaviour during Human-Machine-Interaction, successful strategies of operators are of specific interest. One way to observe these strategies is through eye tracking. An individual‘s spatial working memory capacity (SWMC) has the potential to influence both problem solving (Wiley & Jarosz, 2012) and gaze behaviour (Theeuwes, Belopolsky & Olivers, 2009). In theory, a higher capacity provides the individual with the ability to hold more information active in their memory and direct their attention in a more focused way (Cowan, 2010). However, SWMC is not commonly assessed in the empirical exploration of problem solving and gaze strategies and thus its influence is unclear.

Aim: Investigate the impact of SWMC on eye movements during problem solving in relation to the phase of problem solving (PPS) and the problem difficulty (PD).

Method

The **sample** consisted of $N = 34$ participants ($n = 14$ female, $n = 20$ male) with a mean age of $M = 24.6$ ($SD = 3.3$) years.

The **experimental setup** included a within-subject design with two consecutive tasks (Tower of London, Corsi Block Tapping Task), both presented with PEBL on a 24in LCD screen at 60Hz frame rate.

- *Tower of London*: three levels of difficulty in randomized order with 15 trials each, consisting of a repetition of five trials in alternated color scheme
- *Corsi Block Tapping Task*: forward and backward recall of a tapping sequence with a maximum of two tries for each sequence length

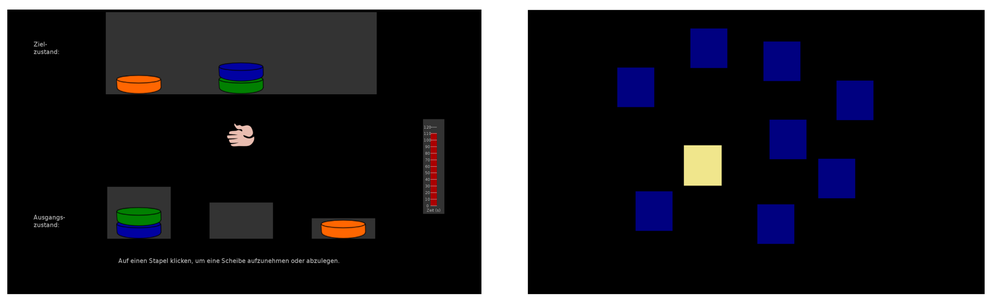


Fig.1: Tower of London (left) and Corsi Block Tapping Task (right)

As **dependent variables** the eye movements were tracked using the SR Research EyeLink 1000 Plus system with a frame rate of 2000Hz.

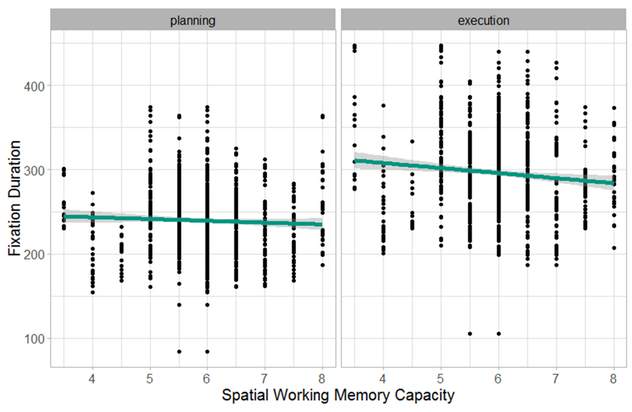
- *Fixation duration*: To eliminate outliers, only fixations with a maximum duration of 1000ms were included in the analysis.
- *Coefficient K*: discerning ambient ($K < 0$) from focal ($K > 0$) attention as ratio between fixation duration and saccade amplitude (cf. Krejtz et al. 2016)
- *Direction of gaze movement*: We distinguished between vertical (-1) and horizontal (1) movements (between vs. within start and goal state).

Results

The data was analysed as linear mixed effects model using R and the packages lme4 and lmertest with random intercepts for the direction of Corsi Block Tapping Task and for the subjects. Visual inspection of residuals yielded no obvious deviations from model requirements.

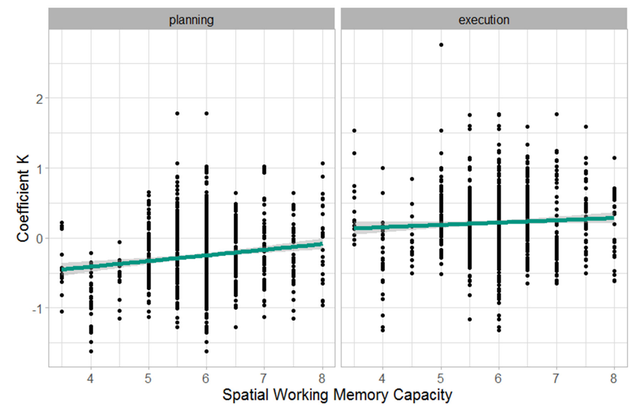
Fixation Duration

- $AIC = 19398$ ($AIC_{Null} = 20784$)
- Significant main effect for PPS $F(1,62754) = 64.64$, $p < .001$, but not SWMC $F(1,11) = 0.01$, $p > .92$
- Significant ordinal interaction between SWMC and PPS $F(1,4872) = 5.02$, $p = .025$ and between PD and PPS $F(2,182074) = 187.54$, $p > .001$



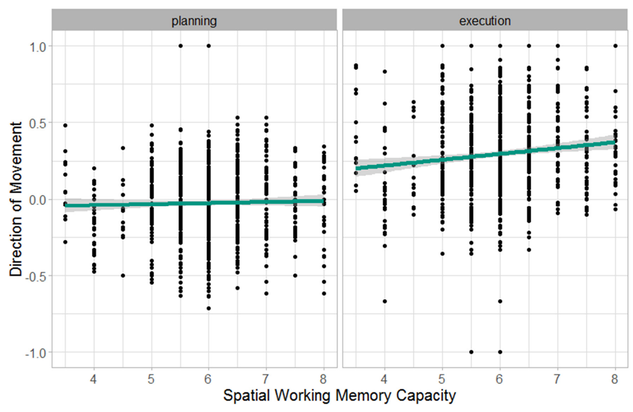
Coefficient K

- $AIC = 1132$ ($AIC_{Null} = 2320$)
- Significant main effect for PPS $F(1,5.72) = 60.83$, $p < .001$ and PD $F(2,0.32) = 3.45$, $p = 032$, but not SWMC $F(1,0.00) = 0.03$, $p > .87$
- Significant ordinal interaction between SWMC and PPS $F(1,0.83) = 8.81$, $p = .003$ and between PD and PPS $F(2,22.17) = 236$, $p > .001$



Direction of Movement

- $AIC = -108$ ($AIC_{Null} = 879$)
- Marginal significant main effect for PPS $F(1,0.18) = 3.56$, $p = .059$, but not SWMC $F(1,0.01) = 0.15$, $p > .695$
- Significant ordinal interaction between SWMC and PPS $F(1,0.35) = 6.85$, $p = .009$ and between PD and PPS $F(2,8.55) = 166.07$, $p > .001$



Conclusion

While problem difficulty plays an inferior role in predicting eye movements, the phase of problem solving emerges as strong predictor. Contradictory to our expectations, spatial working memory capacity has shown no overall effect on the chosen indicators of focused attention. Instead it holds moderating qualities on the relationship between the phase of problem solving and the three indicators. The underlying mechanisms of this relationship stay unclear as spatial working memory capacity shows an inconsistent impact on gaze behaviour during planning versus executing activities. Following the findings here, it can be concluded that spatial working memory should be especially addressed whenever the process of problem solving is to be examined, for easy as well as hard tasks.

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