Of numbers and other uncertainties

Benford's bias as a window into the processes underlying embodied decision making?

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Background

Understanding the principles underlying decision making under uncertainty has been in the research focus of psychology and economics for decades. In everyday life, we also regularly decide upon motor actions to be performed. Though, motor decision making has not been widely investigated, yet. Importantly, motor decision making research has proven powerful in investigating the cognitive and motor processes underlying and evolving during the process of decision making by analysing the kinematic characteristics of the executed movements. However, while this line research was able to link changes in motor behaviour to experimentally induced changes in environmental and task conditions, predicting the dimension and extent of these behavioural changes has not been realized, yet, as a formal description of changes in decision uncertainty, induced by changes in environmental and task conditions, remains a methodological challenge. In the planned research project a well-established psychological decision bias, namely Benford's bias for number estimation, will be used to overcome this challenge.

Project aim:

This project aims at establishing a formal link between psychological theories of decision making under uncertainty, in the context of number estimation, and empirical evidence on uncertainty-induced changes in movement execution stemming from the field of human movement science.

Embodied Decision Making

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 (Figure 1, Cisek, 2007; Cisek & Kalaska, 2010; van Ede & Nobre, 2023).

Motor decision processes can be probed in real-time by analysing kinematics of the executed movements. This is reflected in parameters quantifying action selection and action execution (Figure 2, Gallivan & Chapman, 2014; Gallivan et al., 2018, Krüger & Hermsdörfer, 2019; Krüger et al., 2024).

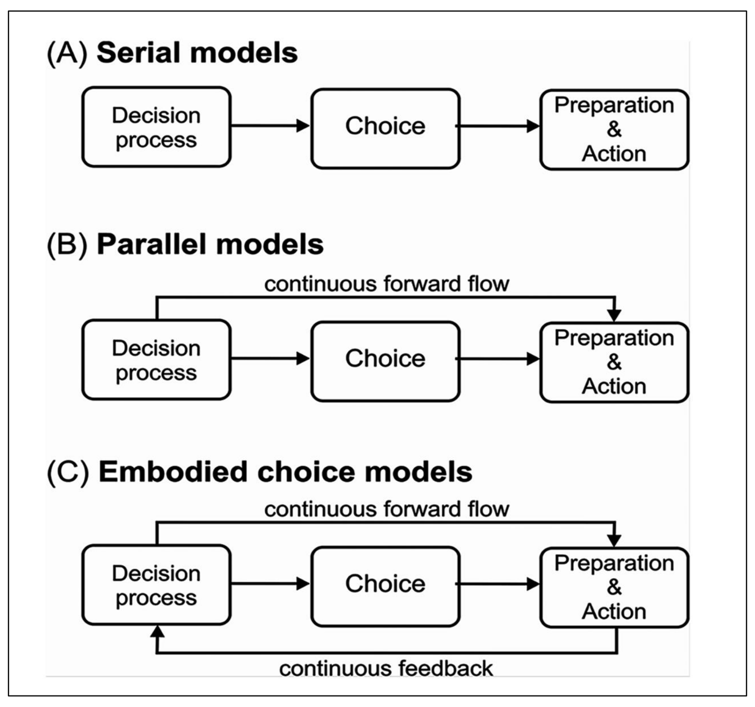


Figure 1: Schematic presentation of potential links between decision and action in motor decision making (figure from Lepora & Pezzulo, 2015, p. 3)

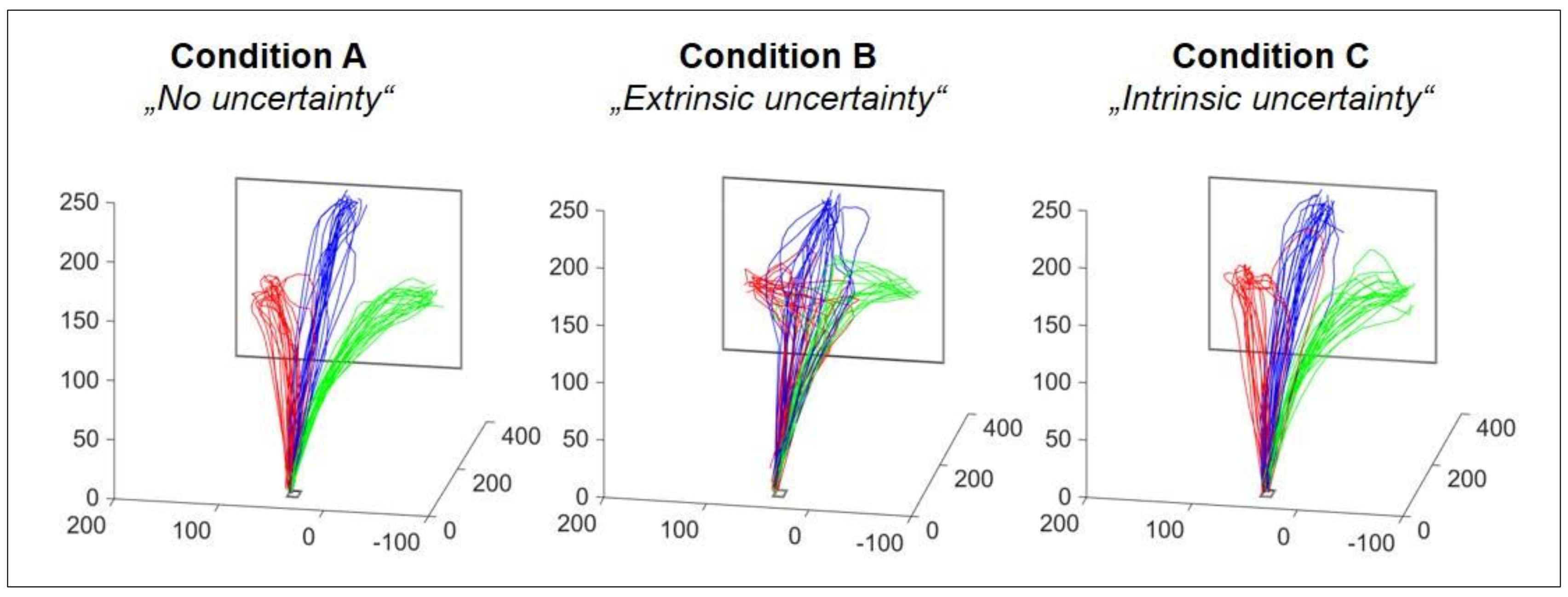


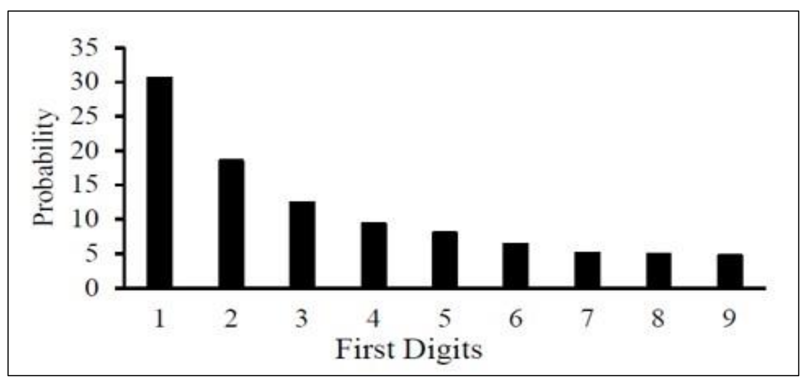
Figure 2: Reach trajectories for three different conditions of a motor decision making task under varying levels of uncertainty (figure from Krüger & Hermsdörfer, 2019, p. 8)

Classical Decision Making

Research on decision making under uncertainty has revealed implicit biases (Figure 3) and heuristics referred to when performing fast decisions, but not when sufficient time is available or when additional cognitive resources are invested, often explained within the context of so-called dual-process models (Kahneman & Egan, 2011). Recent research stimulated discussions on the deliberation process, which is suggested to proceed in the presence of uncertainty between choice options (de Neys, 2024).

Benford's bias in number estimation:

Figure 3: The percentage of times the digits 1 to 9 are used as first digits, as determined from 20229 observations (Benford, 1938, figure from Chi & Burns, 2022).



Experimental Task

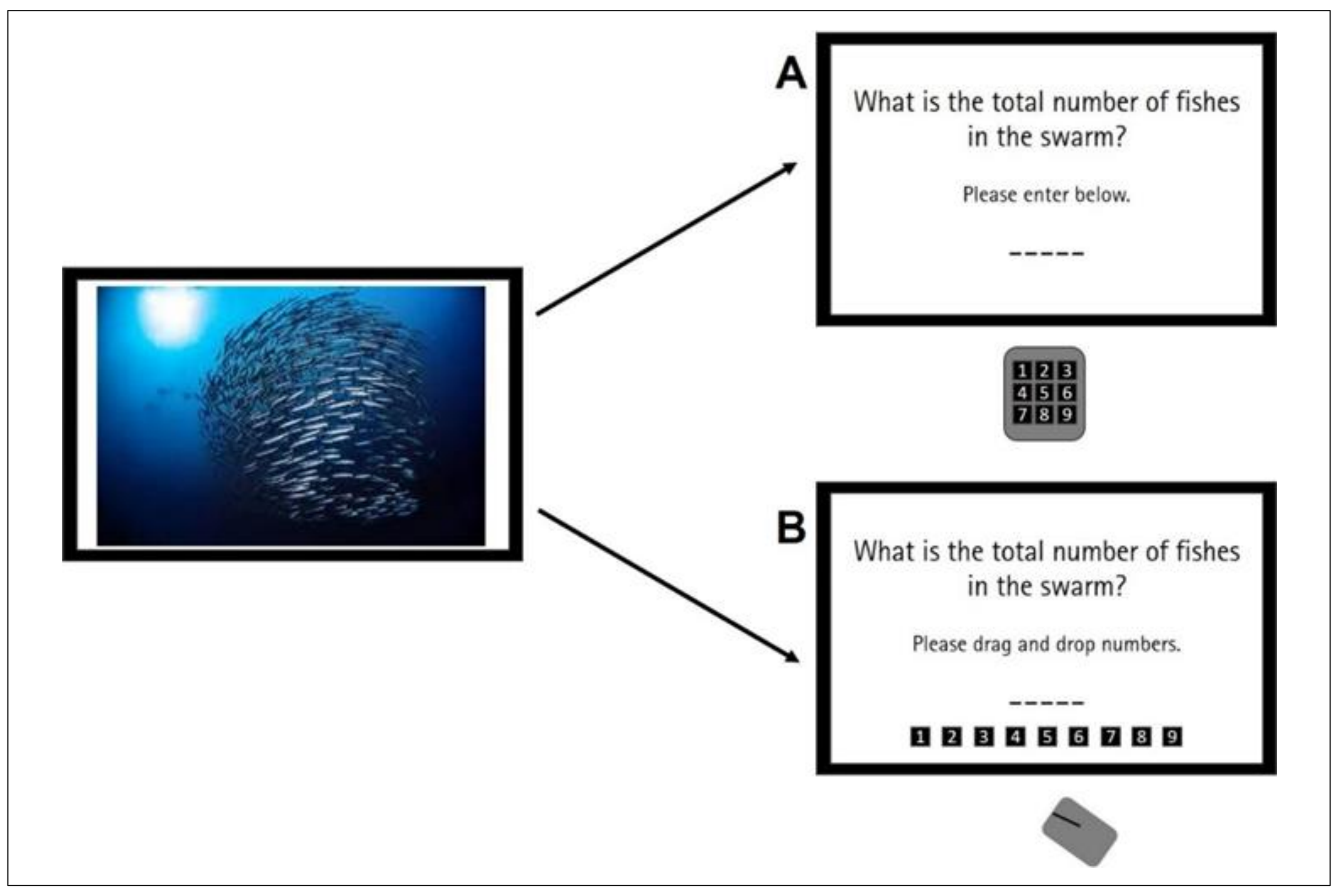


Figure 4: Schematic display of (A) the original (Chi, 2024) and (B) the planned experimental procedure for an exemplary trial, with the latter using mouse tracking for being able to analyse the process of decision making.

Gap of Knowledge

Embodied decision making:

√ Motor behavioural changes when decisions are performed under uncertainty

? Prediction and modelling of the amount and direction of behavioural changes

Classical decision making:

√ Dual-process accounts for fast decision making and further deliberation under uncertainty between choice options

? Experimental approaches able to reveal the ongoing competition between choice options

⇨ Benford's bias as a starting point and analytical tool to predict the size of decision bias in a motor decision making task?

Outlook

The outcomes of this project have the potential to advance theoretical reasoning in the context of embodied decision making in both psychology and human movement science, by integrating scientific methods and findings.

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