Repetition effects in extrinsic and intrinsic coordinates reveal shared representations of movement sequences across the two hands

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Intro: motor sequence representations

The brain maintains representations of sequences of finger presses in premotor and parietal areas (Yokoi et al.,2019). However, such representations could correspond to:

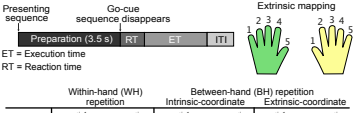
1) The numbers / cues used (**visual** or symbolic representation)
2) Key positions (**extrinsic** or environmental coordinates)
3) In terms of the necessary muscle commands (**Intrinsic** or body-centered coordinates)

To tease apart these possible representations, here we used the behavioural phenomenon of the **repetition effect**: immediate sequence repetition improves execution compared to executing a different sequence (Ariani et al., 2020).

Sequences could repeat **within the same** hand or **from one hand to another**. Repetition across hands could occur in extrinsic coordinate (same key positions, different fingers) or intrinsic (different key positions, mirror-symmetric fingers) coordinate frame.

Q1: Are the representations underlying the repetition effects effector-independent or effector-specific?
Q2: If effector-independent, do they exist in extrinsic or intrinsic coordinates?

Exp 1: effector–independent sequence representations?

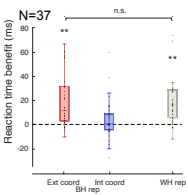


	Within-hand (WH) repetition	Between-hand (BH) repetition Intrinsic-coordinate	Between-hand (BH) repetition Extrinsic-coordinate
	$trial^{i-1}$ → $trial^{i}$	$trial^{i-1}$ → $trial^{i}$	$trial^{i-1}$ → $trial^{i}$
Example	1-5-4-2-3 → 1-5-4-2-3 1-5-4-2-3 → 1-5-4-2-3	1-5-4-2-3 → 5-1-2-4-3 1-5-4-2-3 → 5-1-2-4-3	1-5-4-2-3 → 1-5-4-2-3 1-5-4-2-3 → 1-5-4-2-3
What repeats?	- Hand - Numbers - Fingers - Key positions	- Mirror-symmetric fingers - Numbers	- Numbers - Key positions

In no repetition trials neither the numbers, (mirror-symmetric) fingers, nor key positions are repeated

Sequence representations in intrinsic coordinates

Repetition benefit in RT/ET = RT/ET of no repetition trials - RT/ET of repetition trials
- if positive, repetition improves RT/ET

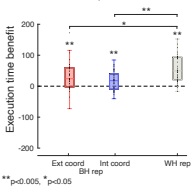


Does the repetition improve the reaction time?

- We found RT benefit for within-hand repetition

- Between hands, we found a RT repetition effect **only** in extrinsic repetition

- This suggests that the benefit in RT can be attributed to the repetition of either the **visual cues** or the **key positions**



Does sequence repetition improves the execution speed of an entire sequence?

- We found ET benefit for both within and between hand repetition

- Participants had no explicit awareness of repeating the mirror-symmetric fingers

- Repetition effect in intrinsic coordinates is evidence for **intrinsic sequence representation**

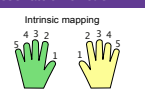
- Do we have any evidence for extrinsic sequence representation?

**p<0.005, *p<0.05

- ET benefit is the largest in within hand repetition. But, the sum of the between hand repetition conditions adds up approximately to the size of within hand effect.

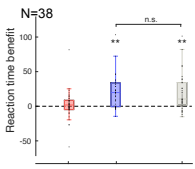
Exp 2: extrinsic sequence representation or cue?

- Same protocol as as Exp. 1
- New group of participants



	Within-hand repetition	Between-hand repetition Intrinsic-coordinate	Between-hand repetition Extrinsic-coordinate
	$trial^{i-1}$ → $trial^{i}$	$trial^{i-1}$ → $trial^{i}$	$trial^{i-1}$ → $trial^{i}$
Example	1-5-4-2-3 → 1-5-4-2-3 1-5-4-2-3 → 1-5-4-2-3	1-5-4-2-3 → 5-1-2-4-3 1-5-4-2-3 → 5-1-2-4-3	1-5-4-2-3 → 5-1-2-4-3 1-5-4-2-3 → 5-1-2-4-3
What repeats?	- Hand - Numbers - Fingers - Key positions	- Mirror-symmetric fingers - Numbers	- Key positions

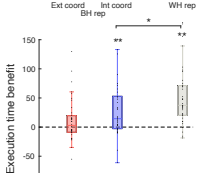
No evidence for extrinsic sequence representation



- Benefit in RT is caused by the repetition of the **visual cues (numbers)**

- Could it be explained by more rapid processing of the visual stimulus when the numbers are repeated?

- Could it be explained by the motivational effect due to explicit knowledge? (Wong et al. 2015)



- Between hand, repetition benefit in ET remained intact in intrinsic coordinate

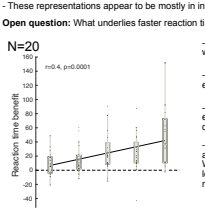
- ET benefit for extrinsic repetition vanished after controlling for repetition in the numbers

- Therefore, in out behavioural paradigm, **we could not found any evidence for extrinsic sequence representation**

Conclusions

- We replicated within hand repetition effects for movement sequences
- We found evidence for effector-independent sequence representations
- These representations appear to be mostly in intrinsic (body-centered) coordinate

Open question: What underlies faster reaction time upon repetition?



- We only observed the RT benefit when the numbers are repeated

- This is compatible with a motivational effect due to explicit knowledge

- To test if this was the case, we explored the RT benefit as a function of sequence length

- If it's about knowledge, we'd expect a constant benefit across loads. We found an increasing benefit with load, suggesting that it might be more related to triggering than motivation

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