Using a hand-held tool modifies proprioceptive representations of the user's arm and tool

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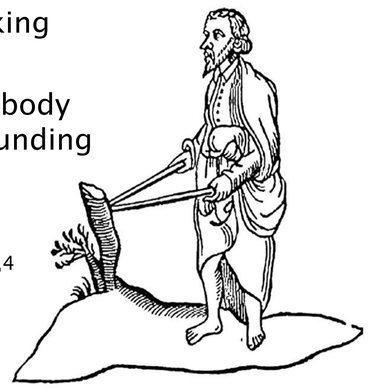
Introduction

- Descartes (1637) recognized that a blind man can use his walking sticks to perceive object distance[1]
- Empirical studies have since demonstrated that extending the body with a tool alters body representation and the perceived surrounding space
- For example, tool extensions have been found to alter:
  - Size and shape of arm and hand representation[2,3,4]
  - Kinematics[5,6]
  - Peri-personal space[4,8]



- However, to the best knowledge of the researcher, whether tool use changes the representation of the tool has not been addressed

Questions addressed in the present study:

1. Do humans have proprioceptive representations of the arm and tool?
2. Does the represented length of the arm and tool change with tool use?
3. Does tool use improve the accuracy of the arm and tool representations? Does one improve more than the other?

Experiment

Proprioceptive Mapping Paradigm

- Participants (n=24) performed a novel proprioceptive mapping paradigm that simultaneously measured proprioceptive maps of the forearm and hand-held tool
- **Task**: Point in the space above the arm or tool to indicate the location of a pre-specified landmark
- Twelve landmarks (10 trials each): 6 landmarks for the arm, 6 landmarks for the tool (0 to 100% by steps of 16.67% actual length)
- Before and after tool use

Tool Use Paradigm

- Use mechanical grabber (40 cm) to move foam pieces and align their shapes
- 10-minutes of tool use in total

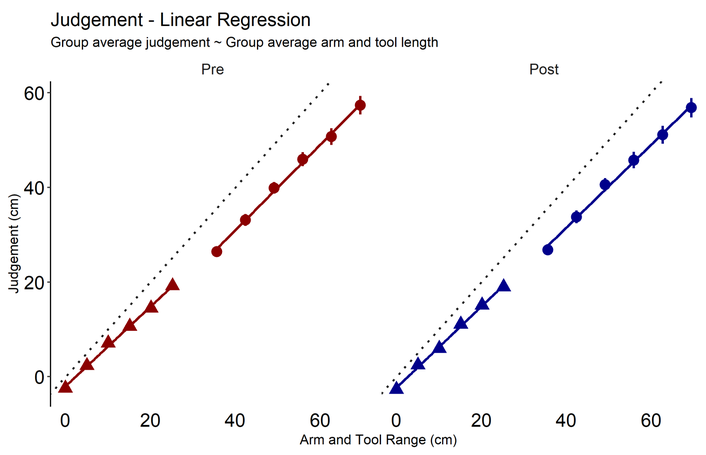
Analysis

- Fitting linear regression to judgements of participants
- Comparing slope and intercept from linear regression models for arm/tool and pre/post
- Comparing constant and variable error for arm/tool and pre/post
- Calculating Euclidean distance between pre and post to compare the change of pattern between tool and arm

Results

QUESTION 1 – Do humans have a proprioceptive representation of the tool and arm?

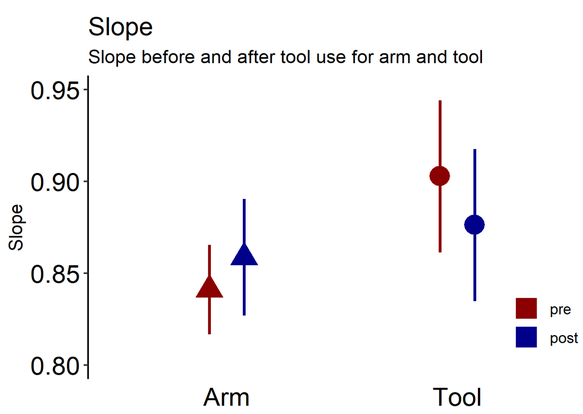
- **Arm representation:** Intercept: -2.04 (pre), -2.33 (post) Slope: 0.84 (pre), 0.86 (post)
- **Tool Representation:** Intercept: -5.01 (pre), -3.57 (post) Slope: 0.90 (pre), 0.88 (post)
- **Conclusion:** Humans have a proprioceptive representation of arm and tool with similar fits to proprioceptive judgements



QUESTION 2 – Does the length of the arm and tool change with tool use?

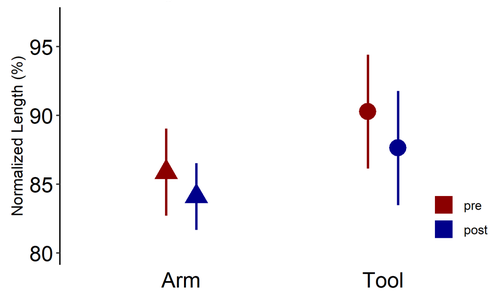
Comparison slope and intercept before and after tool use

- **Repeated measures ANOVA:**
- **Slope:** Main effect of surface: F=0.74, p=.4; Main effect of time: F=0.06, p=.81 Interaction: F=2.17, p=.15
- **Intercept:** Main effect of surface: F=2.27, p=.15; Main effect of time: F=1.04, p=.32 Interaction: F=2.64, p=.12
- **Conclusion:** this study did not find a main effect of surface, time or interaction for slope and intercept



Comparison of regression derived length elbow/wrist and base/tip before and after tool Use

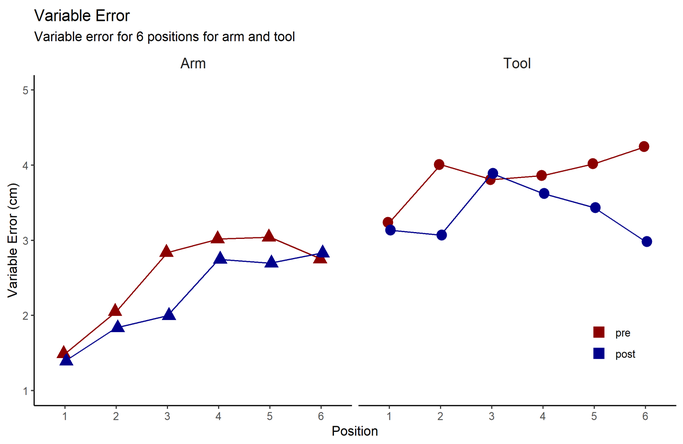
- **Arm representation** length (% of total): pre = 85.9 %, and post = 84.1 %
- **Tool representation** length (% of total): pre = 90.3 %, and post = 87.6 %
- 2x2 repeated measures ANOVA found no main effect for surface, time or interactions (all p >.05)



QUESTION 3 – Does tool use improve the accuracy of the arm and tool representation? Does one improve better than the other?

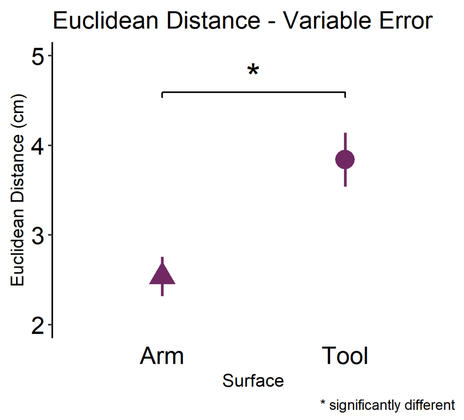
Variable error

- **Arm representation:** Main effect of time: F=6.21, p=0.02; Main effect of position: F=20.58, p<.001; Interaction: F=2.33, p<.05
- **Tool representation:** Main effect of time: F=8.23 p=.01; Main effect of position: F=1.92, p=0.1; Interaction: F=3.24, p=.01



Variable error – Euclidean distance

- **Pattern of change (pre-post):** Arm = 2.537 (cm) Tool = 3.840 (cm) Wilcoxon signed ranked test (p <.001)
- **Conclusion:** this study found a significant difference in the pattern of change (pre-post) for arm and tool with the tool becoming more accurate than the arm



Discussion

- We designed a novel task for mapping the arm and tool at a fine-grained level
- We found that humans have proprioceptive representations of the arm and tool[7]
- The proprioceptive representation of the tool has a similar underestimation of length as the arm representation[8]
- It is unlikely to be an effect of visual-spatial memory[9]
- In contrast with previous findings, we found no change of arm representation length through tool extension and active tool use[1,2,3,4,5]
- However, we found a tool-use induced change of the variable error for arm and tool
- The magnitude of change in variable error before and after tool use was significantly bigger for the tool than for the arm, which suggests tool-use builds a more precise representation of the tool instead of practice effect
- In total, we found that the proprioceptive representations for arm and tool are malleable and can change following tool use

References

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