

# How Long Does It Take to Learn **Trimanual** Coordination?

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Picture: Stelarc photographed by K. Oki

## Traditional



Picture: Curry Health Network, Gold Beach, Oregon

Do you need an extra 'hand'?

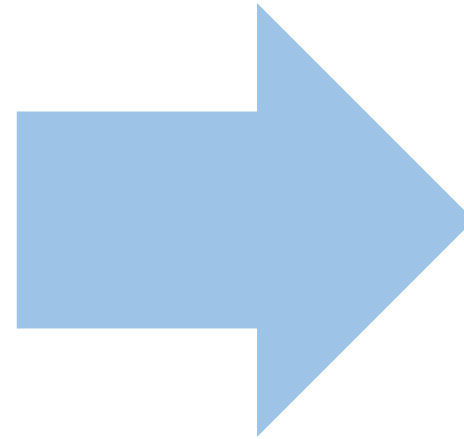
## Traditional



- Miscommunication within a team leads to errors
- Takes time to learn how to work with each new partner
- Difference in views between people

Picture: Curry Health Network, Gold Beach, Oregon

Traditional

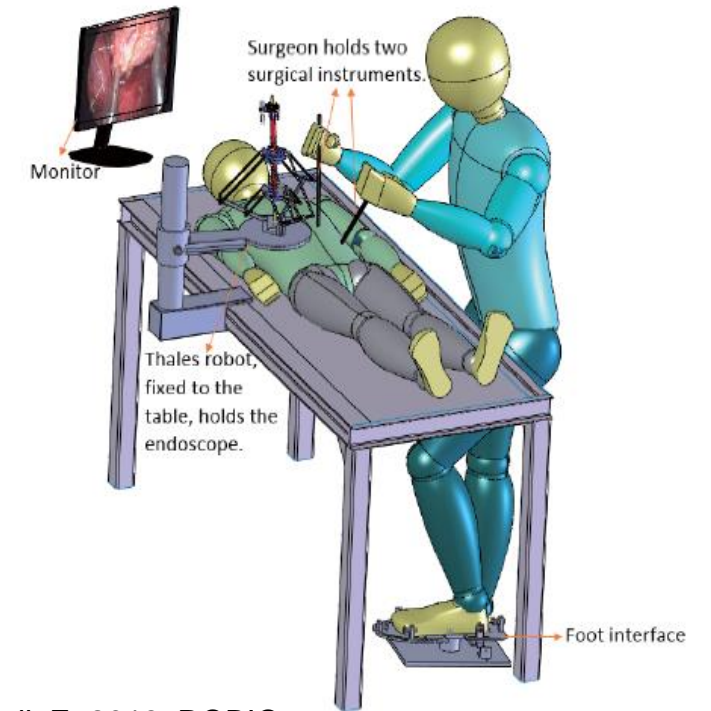


An extra 'hand' is extra

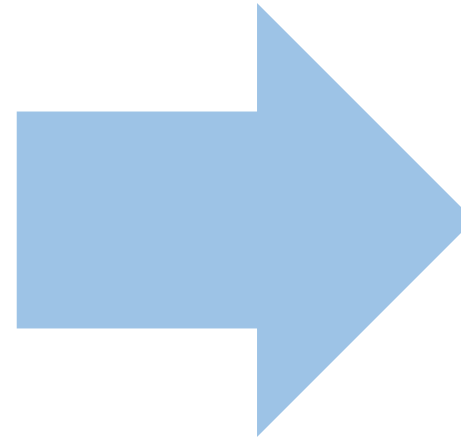
Traditional



Augmented

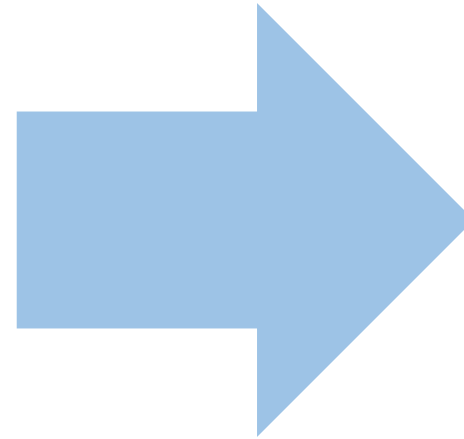


Schematic : Abdi, E. 2018, ROBIO

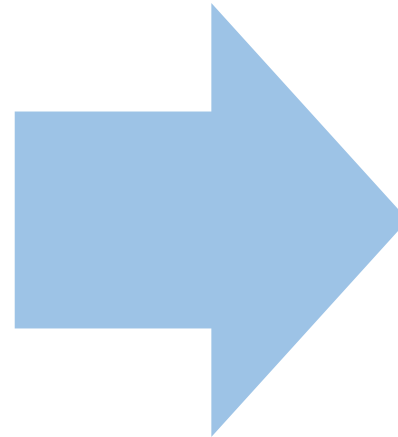


An extra 'hand' is extra

Manufacturing



Office





Picture: Sony Pictures, 2004





Picture: Sony Pictures, 2004

- What tasks is augmentation best suited to?
- Can a human user control additional independent degrees of freedom without sacrificing their natural performance?
- How best to train a user to perform augmentation?

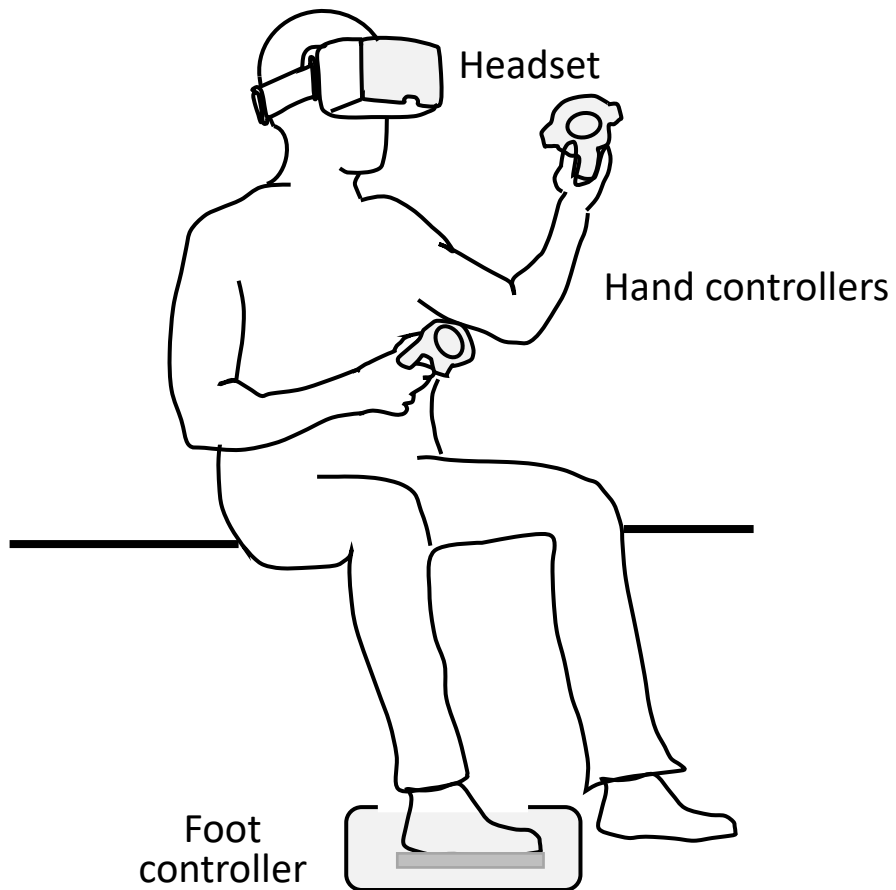


Picture: Sony Pictures, 2004

- What tasks is augmentation best suited to?
- Can a human user control additional independent degrees of freedom without sacrificing their natural performance?

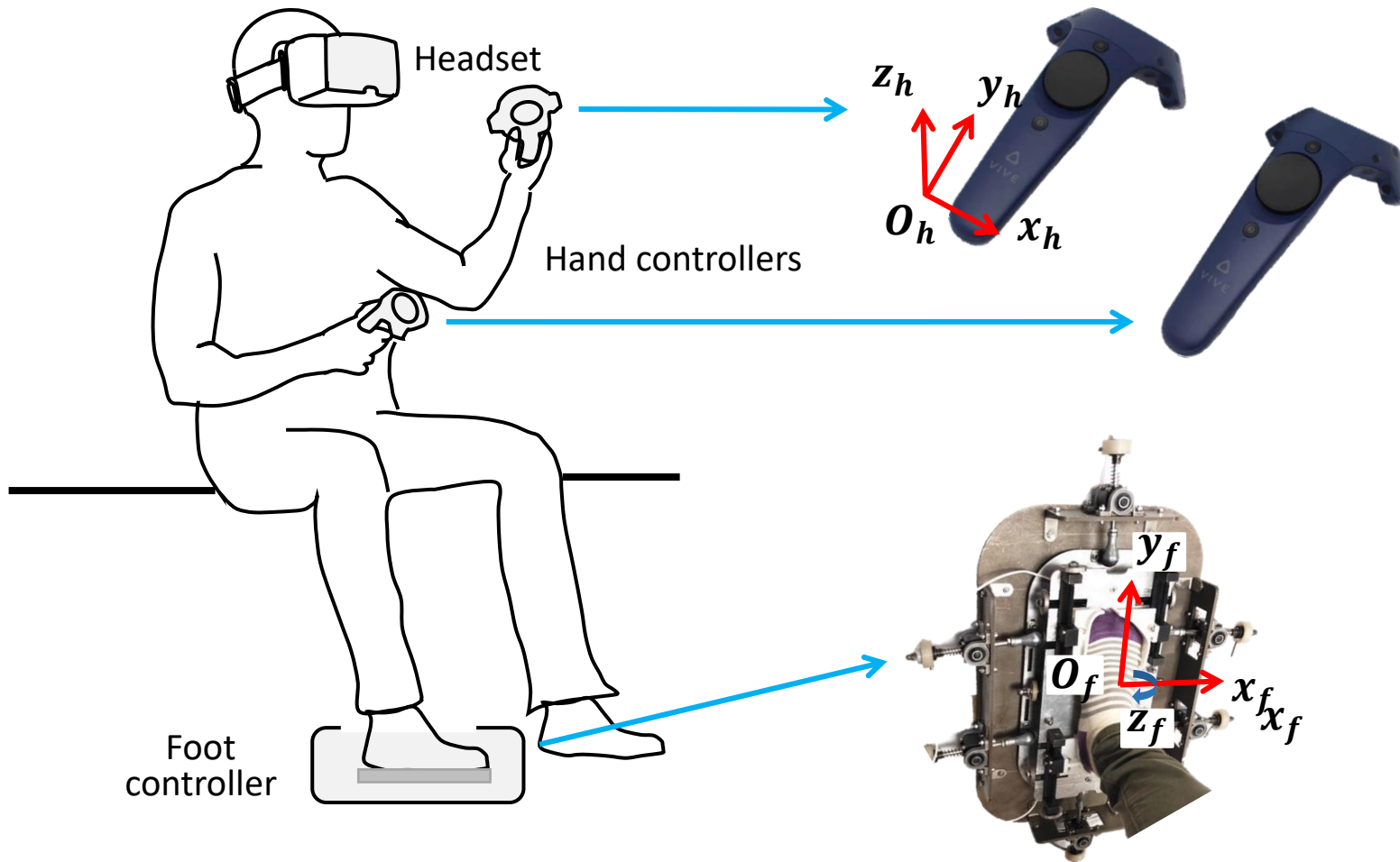
- How best to train a user to perform augmentation?
  - How much training is required to gain trimanual skills?

# Experimental Setup

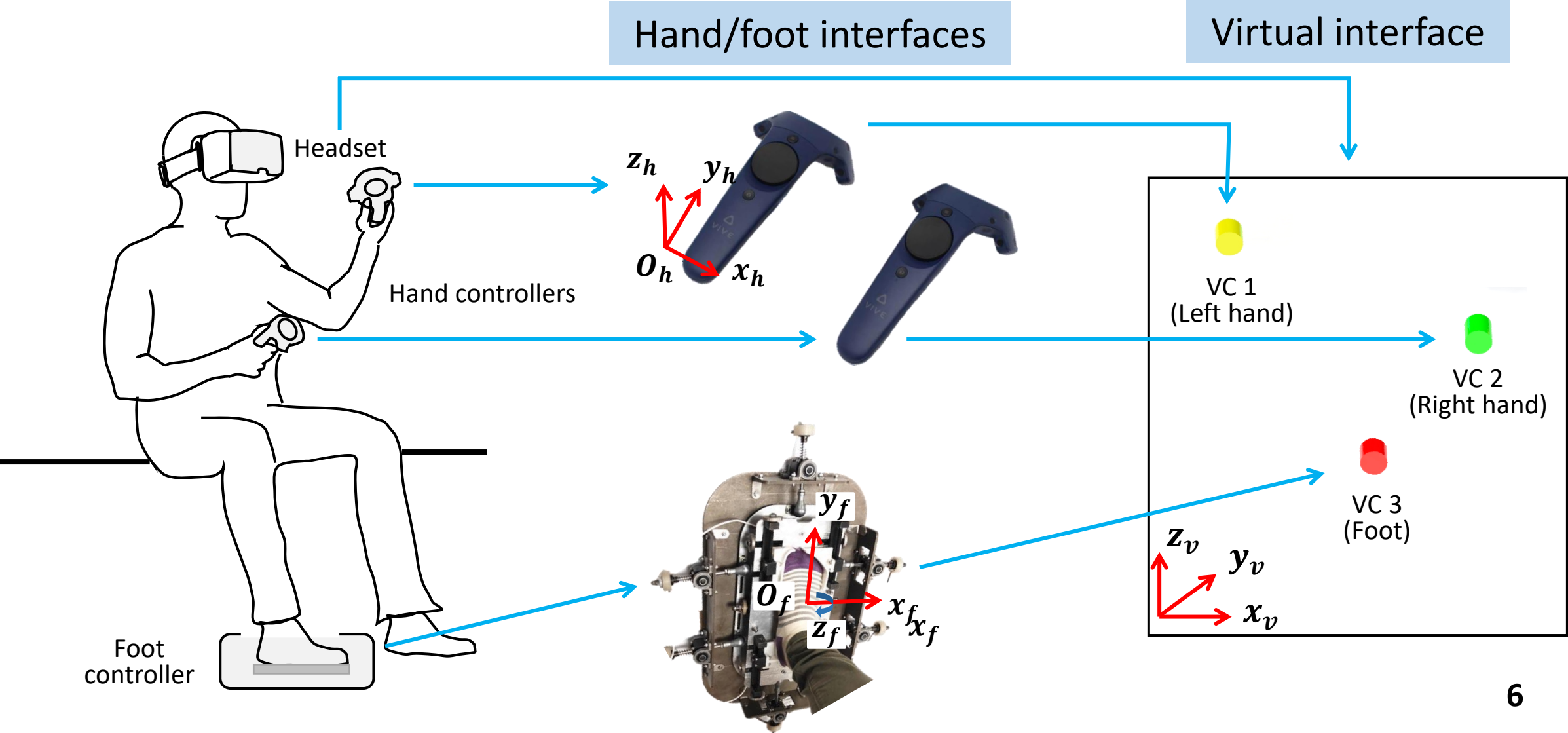


# Experimental Setup

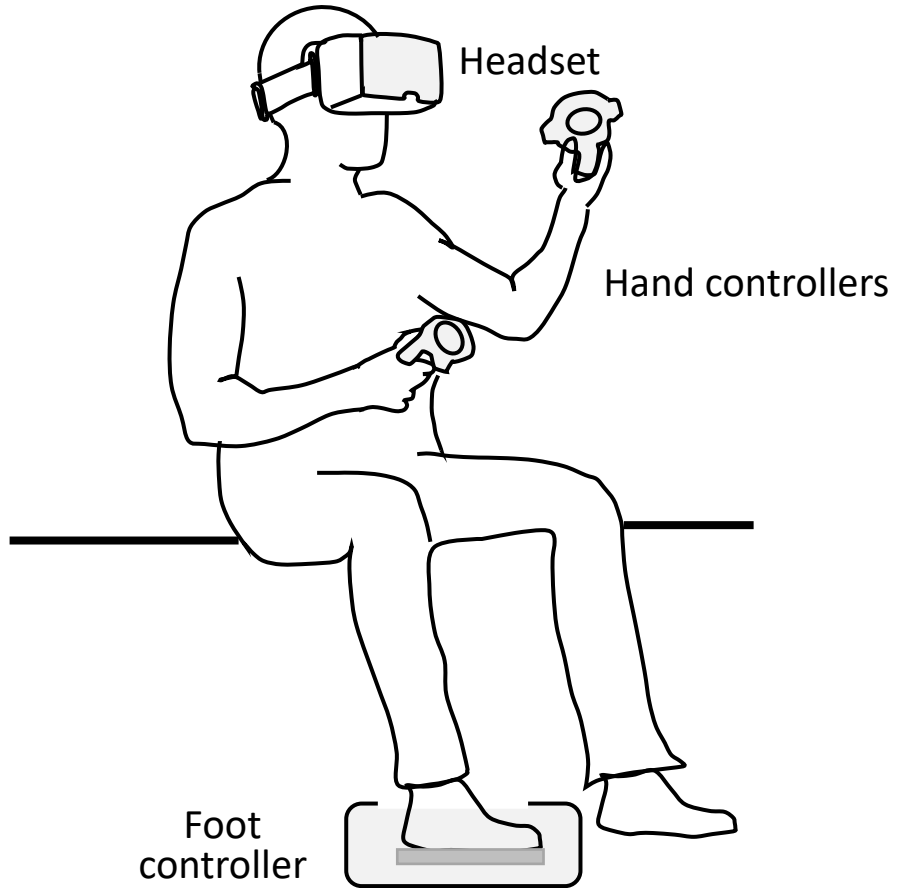
## Hand/foot interfaces



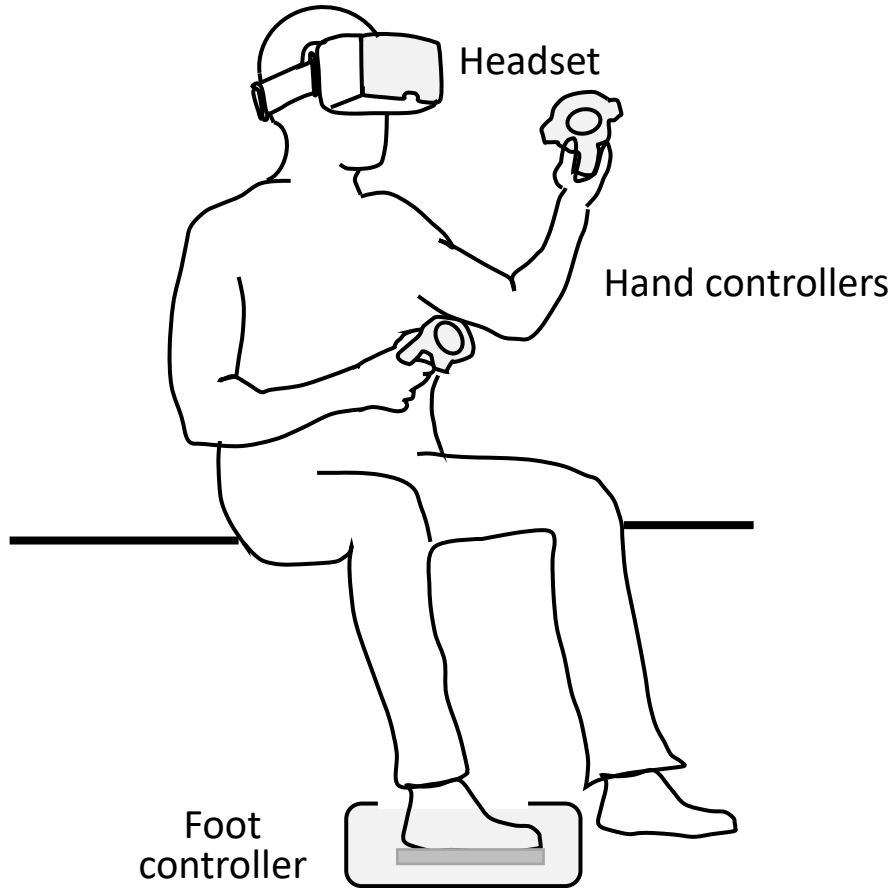
# Experimental Setup



# Tasks



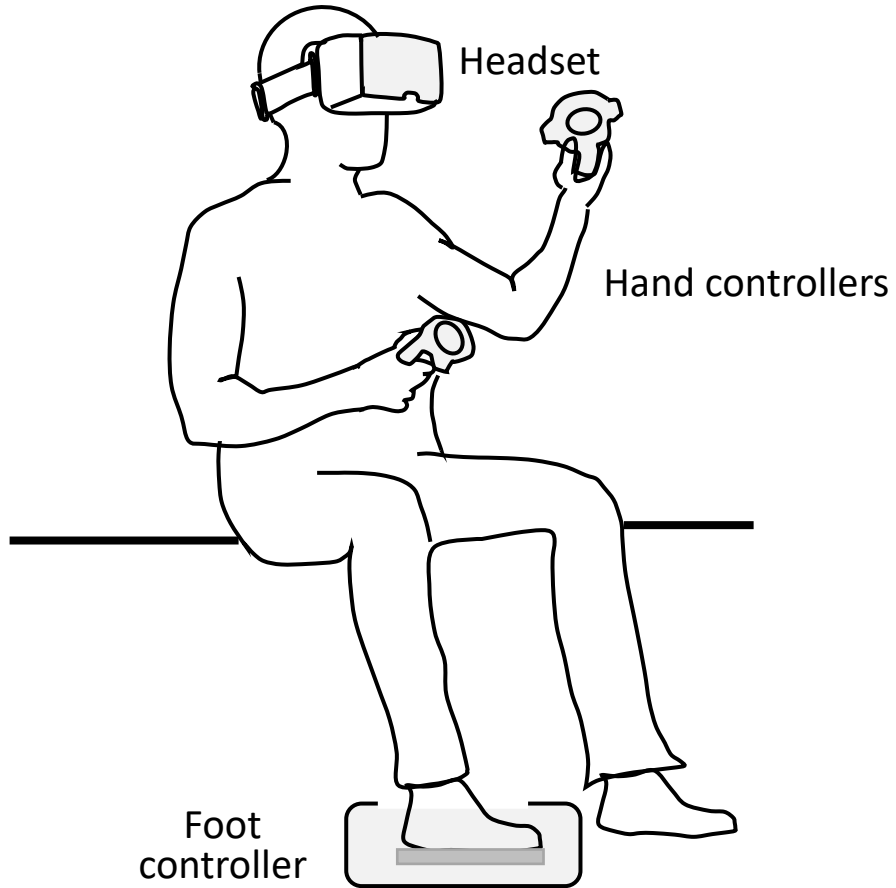
# Tasks



Independent

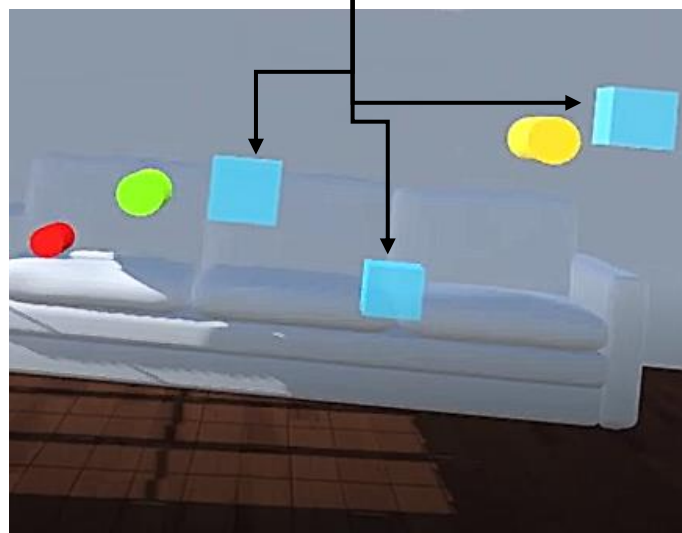
Dependent

# Tasks



Independent

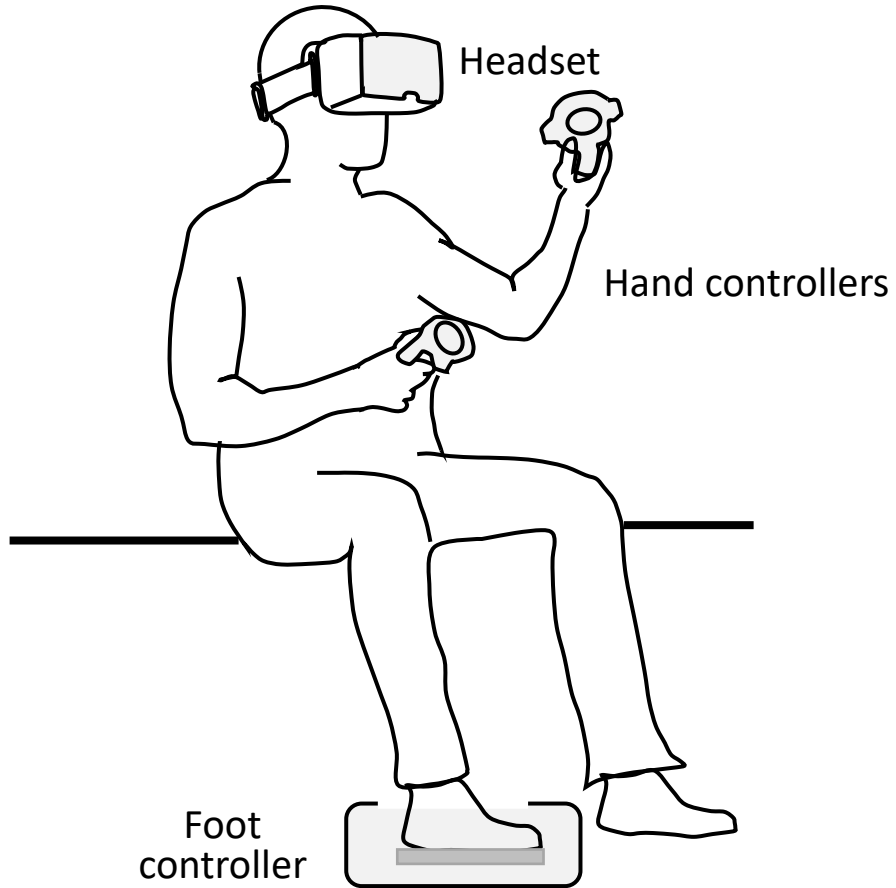
The 3 cursors must be on the different targets at the same time



Dependent

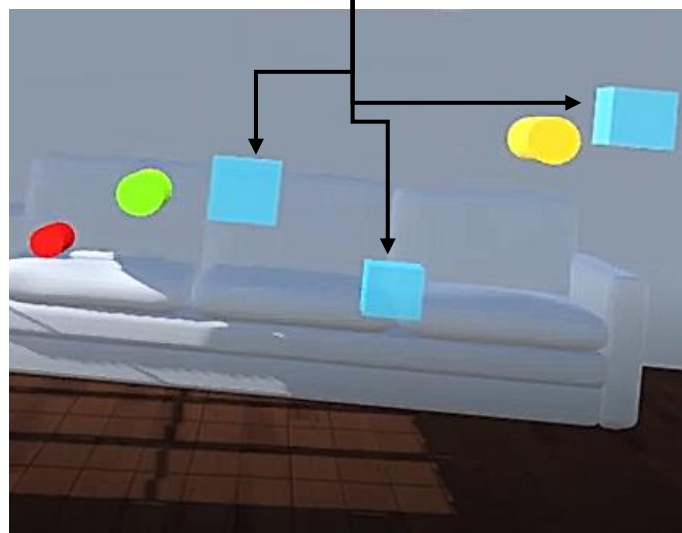


# Tasks



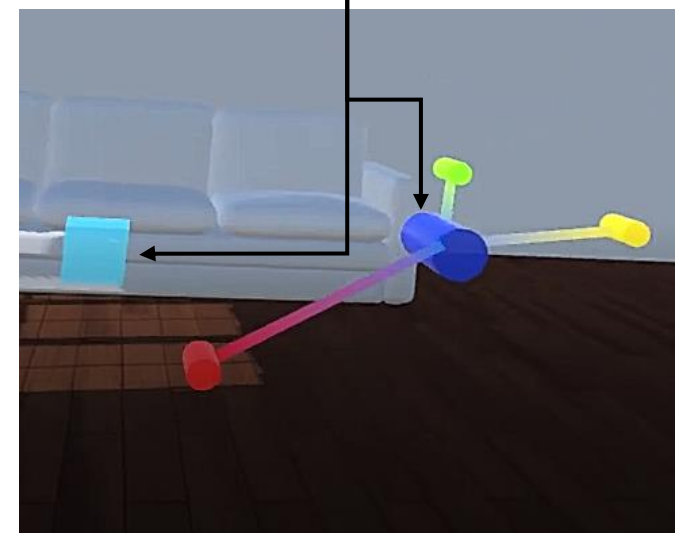
## Independent

The 3 cursors must be on the different targets at the same time

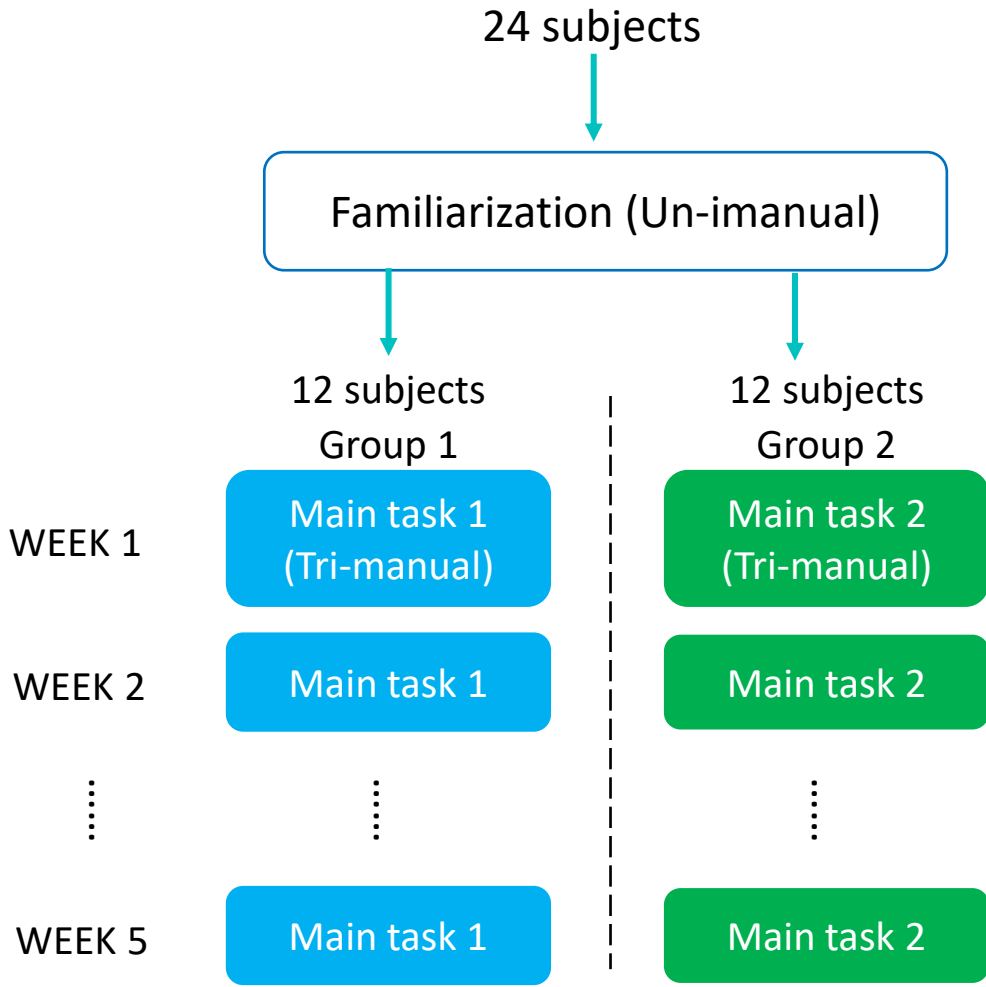
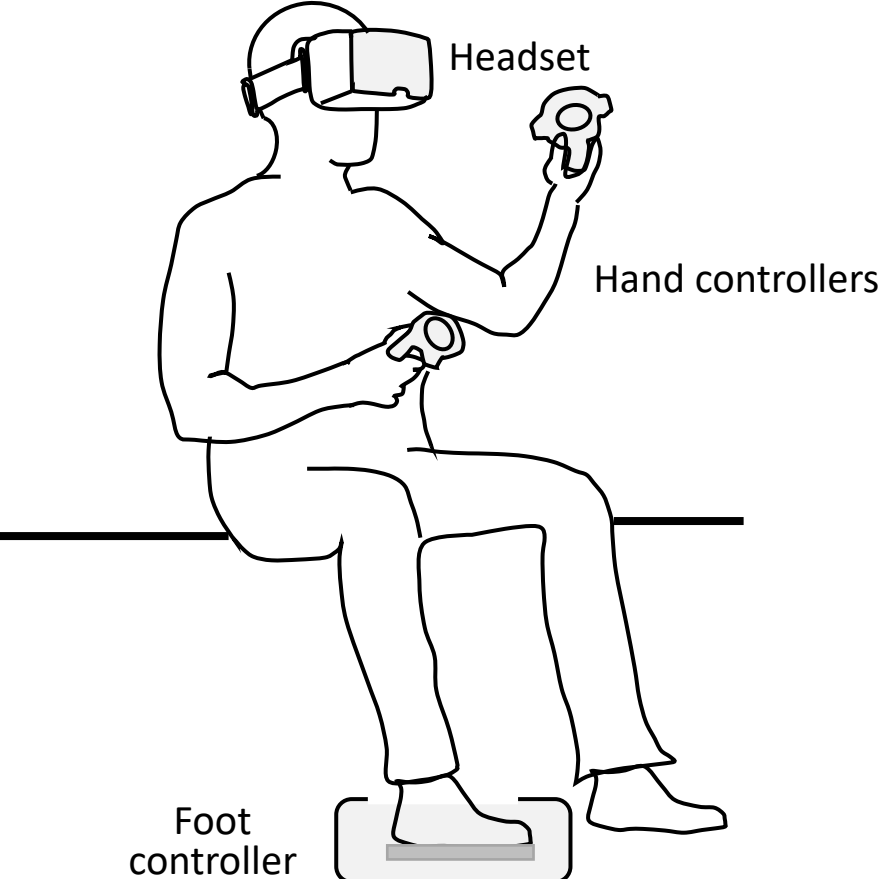


## Dependent

The target must be reached by the cursor COM



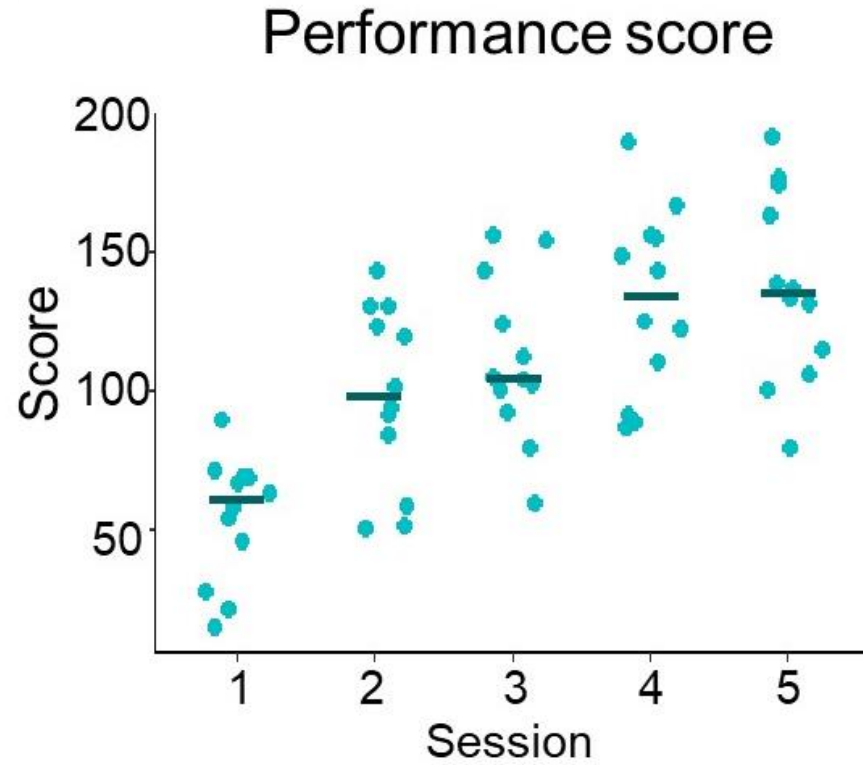
# Protocol





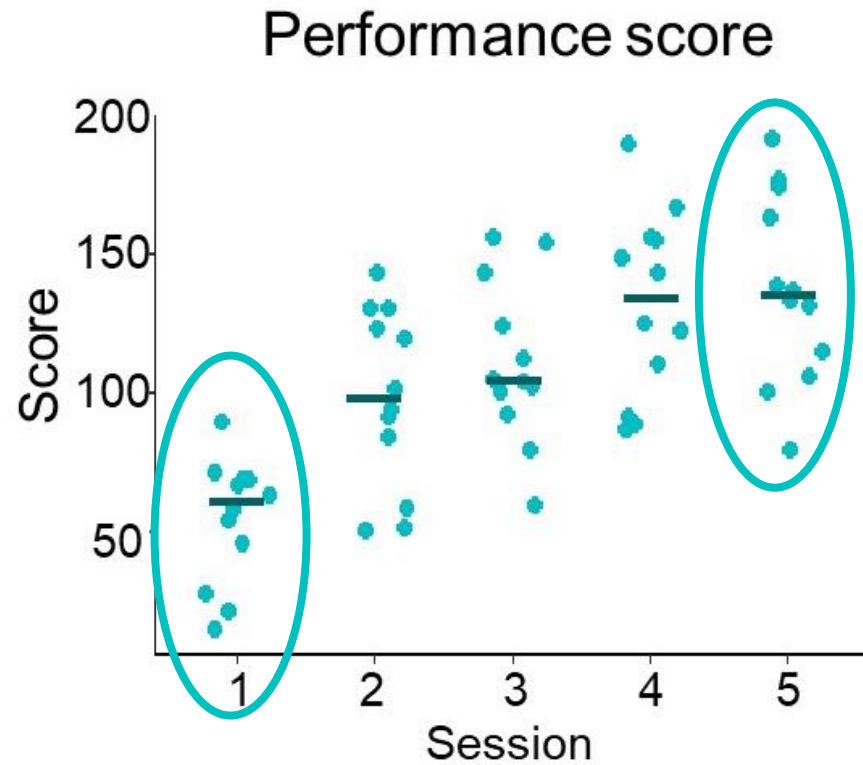
# RESULTS

# Independent Task



# RESULTS

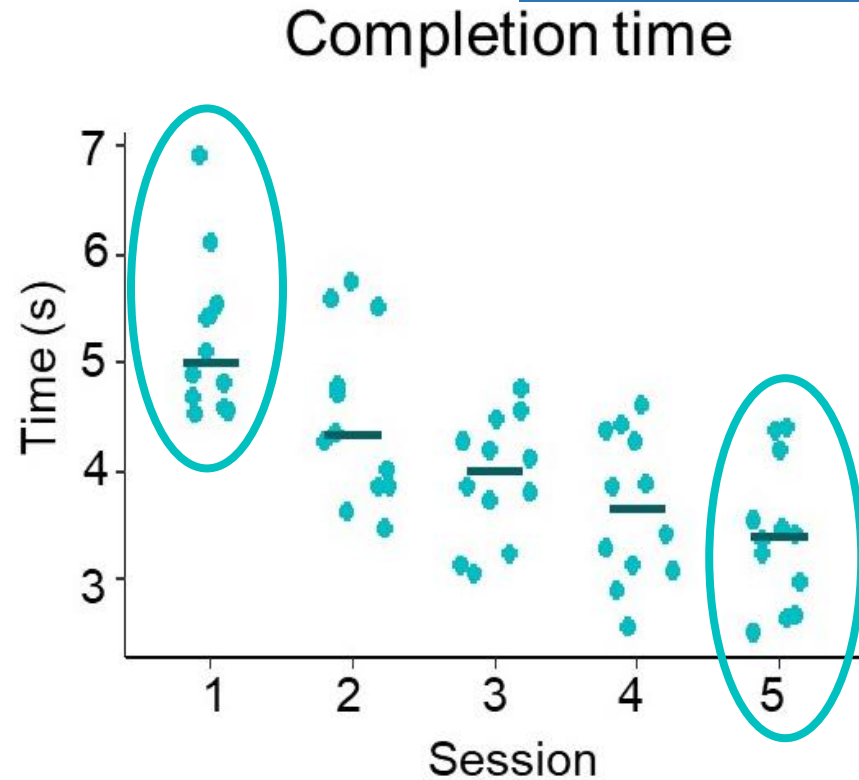
# Independent Task



- Score improvement from Session 1 to 5

# RESULTS

# Independent Task

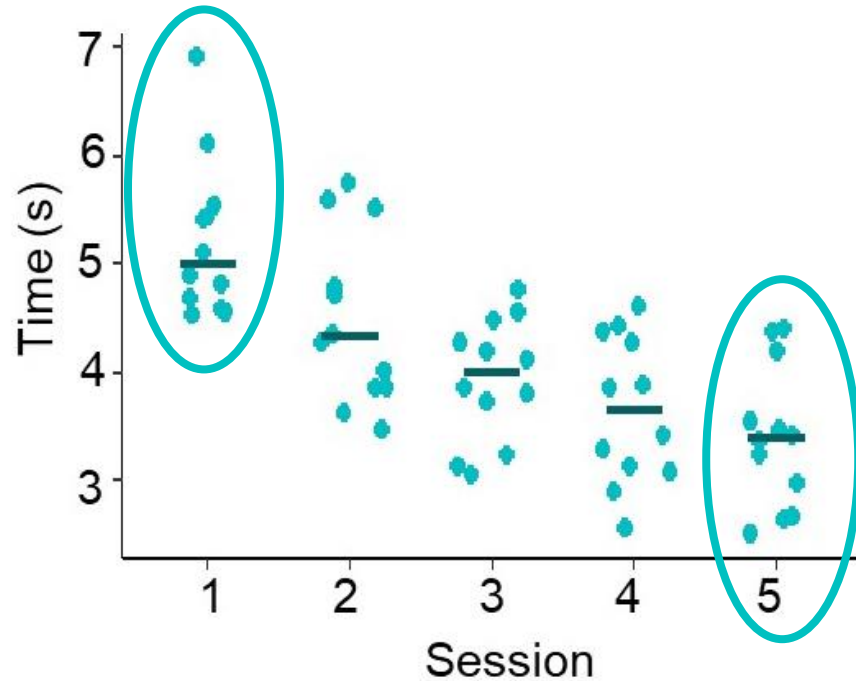


- Score improvement from Session 1 to 5
- Similar tendency for completion time

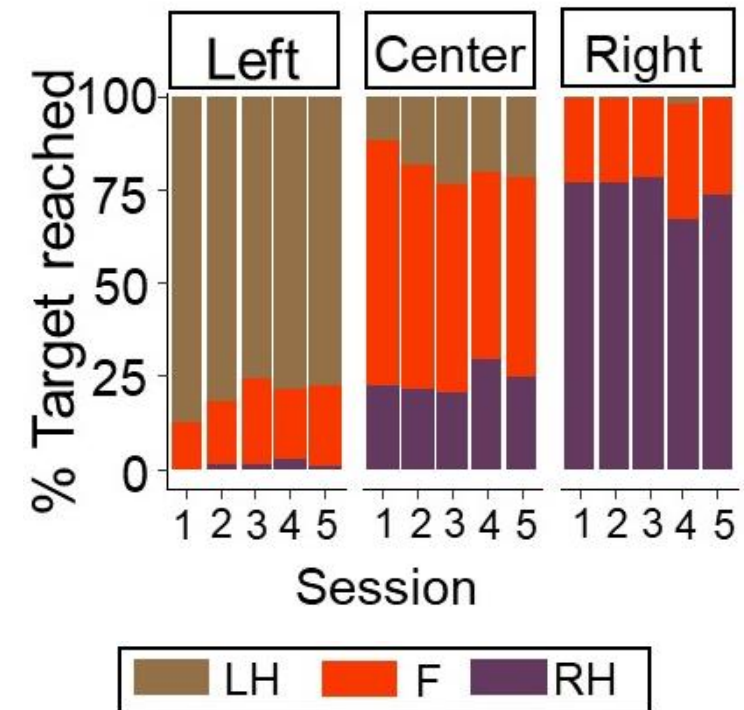
# RESULTS

# Independent Task

Completion time



Target preference per hand

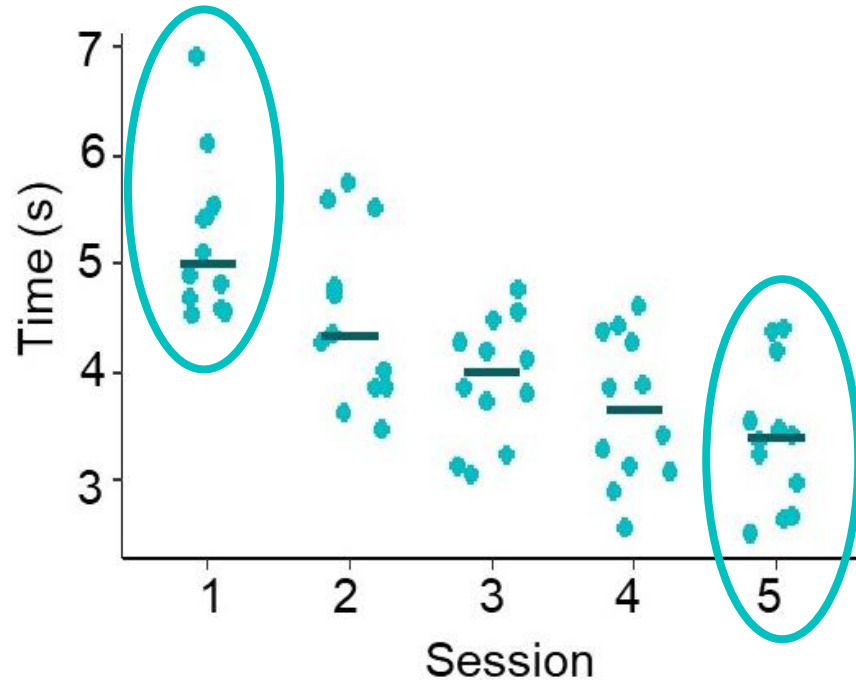


- Score improvement from Session 1 to 5
- Similar tendency for completion time

# RESULTS

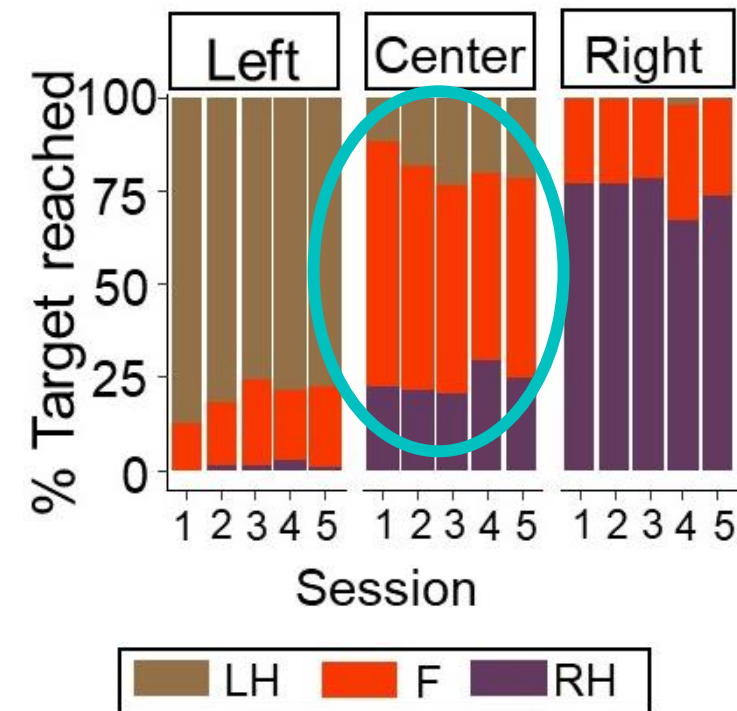
# Independent Task

Completion time



- Score improvement from Session 1 to 5
- Similar tendency for completion time

Target preference per hand



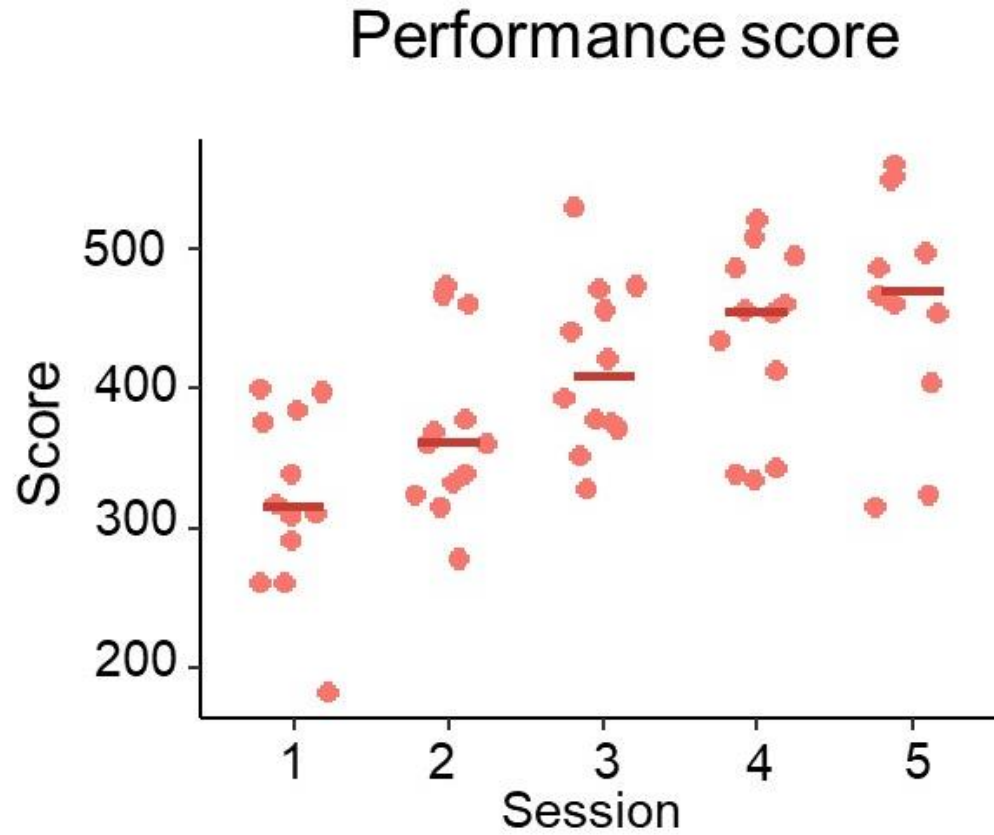
The foot is used to reach the central targets





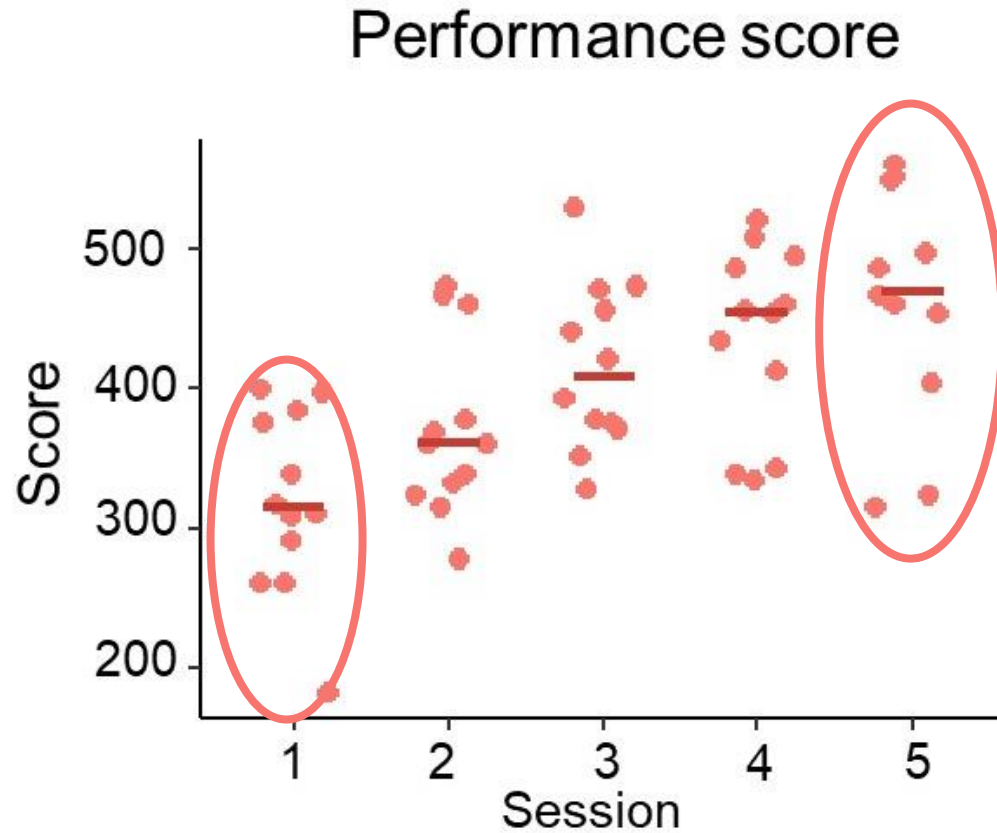
# RESULTS

# Dependent Task



# RESULTS

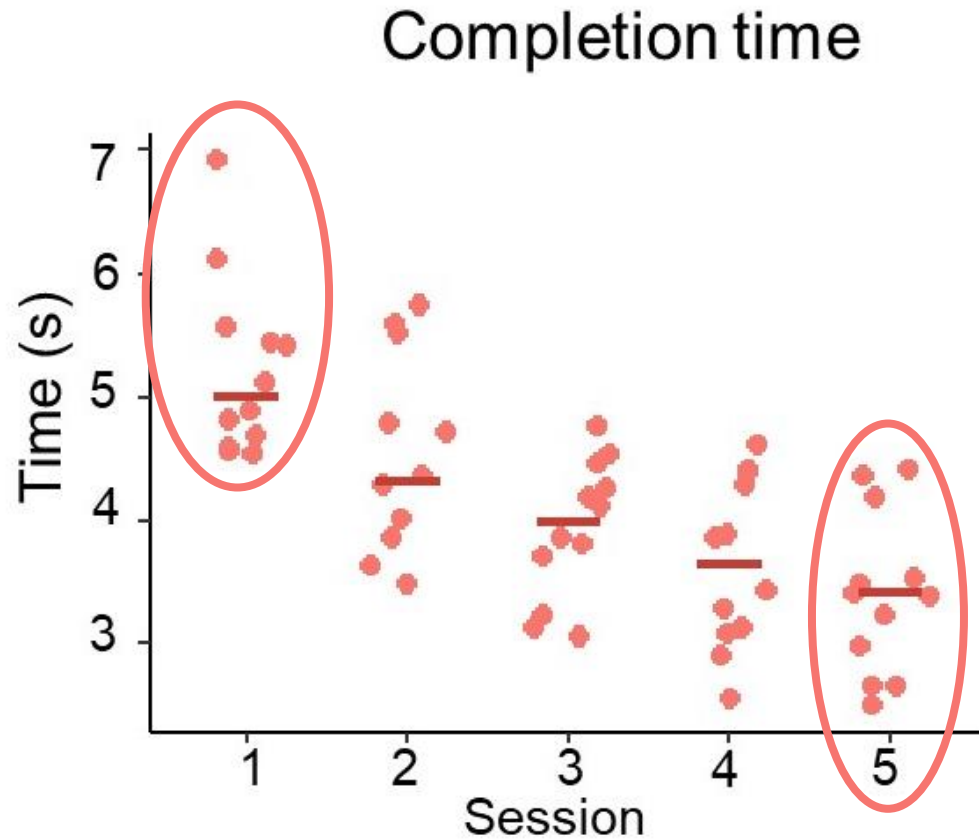
# Dependent Task



Similar tendency than for the Independent Task

# RESULTS

# Dependent Task

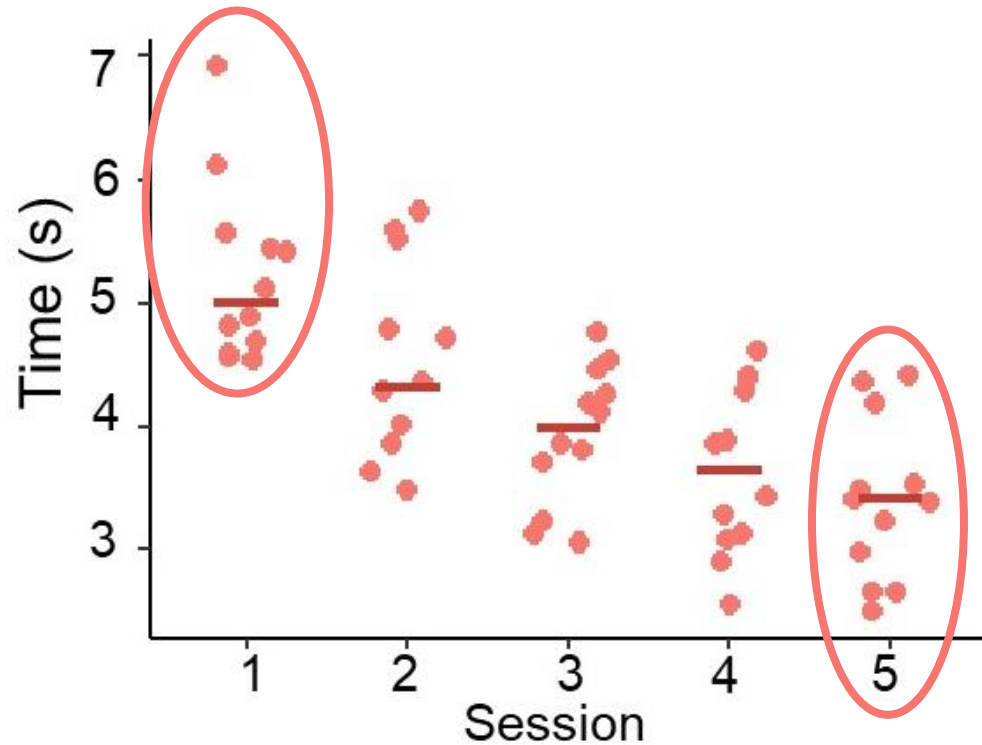


Similar tendency than for the Independent Task

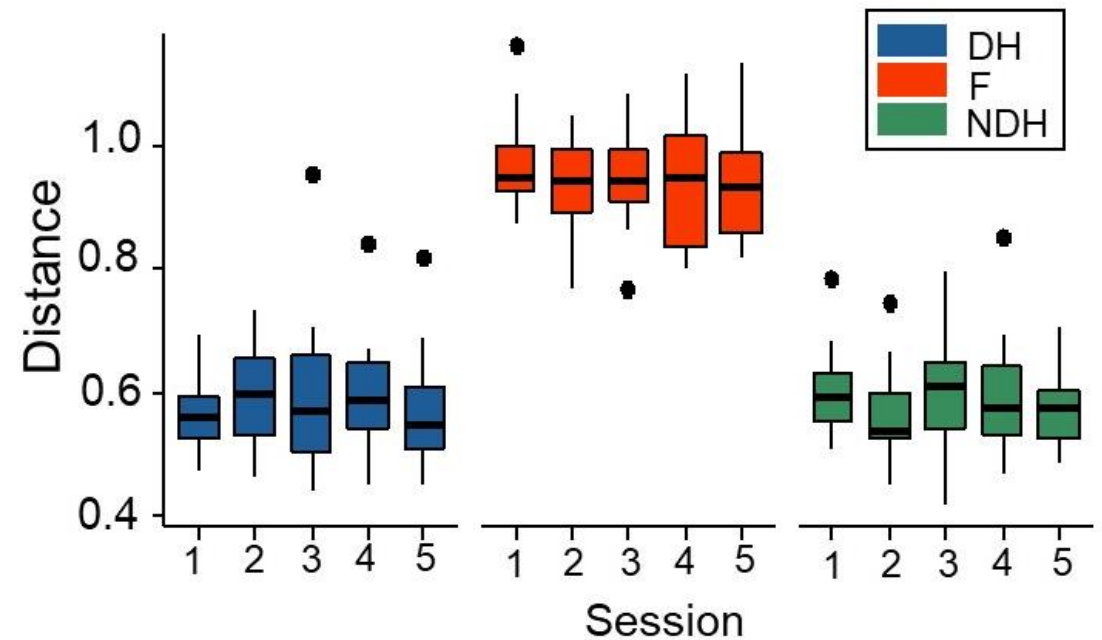
# RESULTS

# Dependent Task

Completion time



Distance to CoM

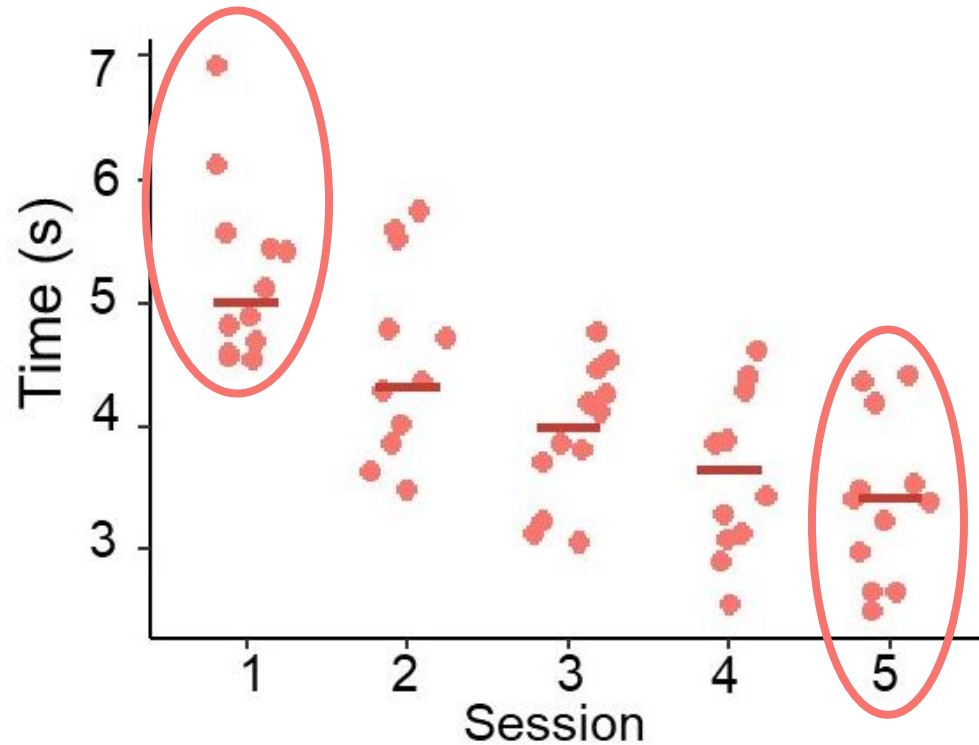


Similar tendency than for the Independent Task

# RESULTS

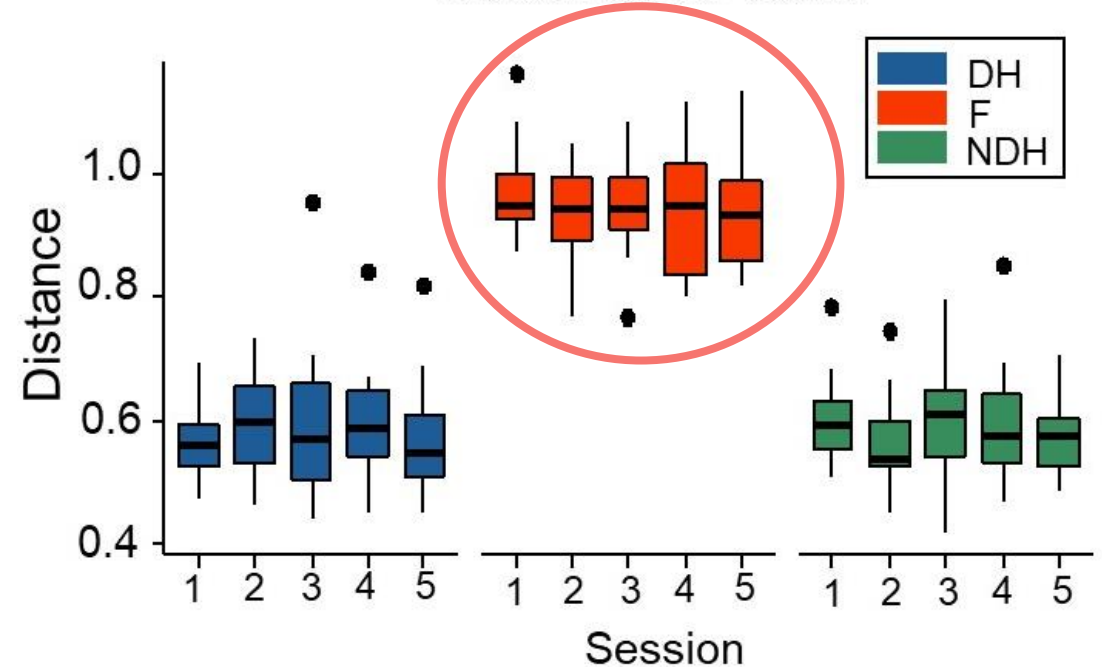
# Dependent Task

### Completion time



Similar tendency than for the Independent Task

### Distance to CoM



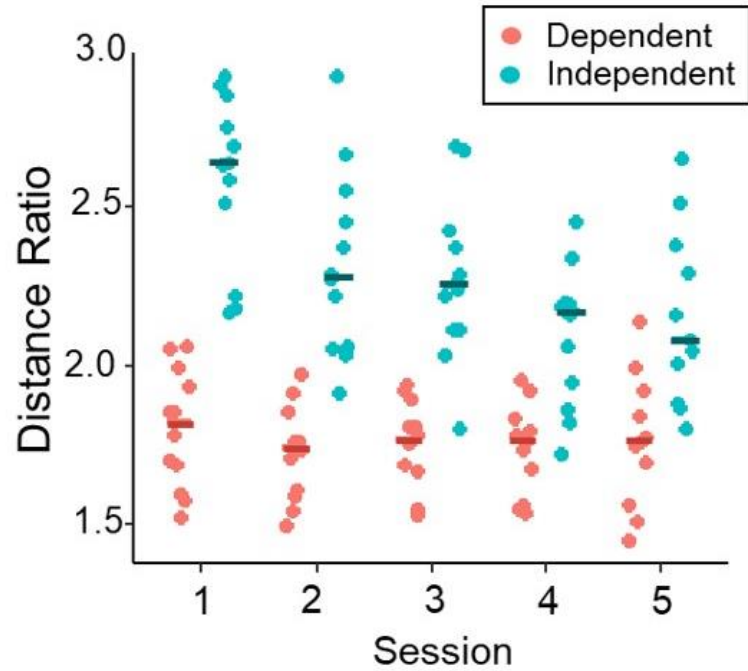
The foot is further away from the COM than the other limbs



# RESULTS

# Comparison - Performance

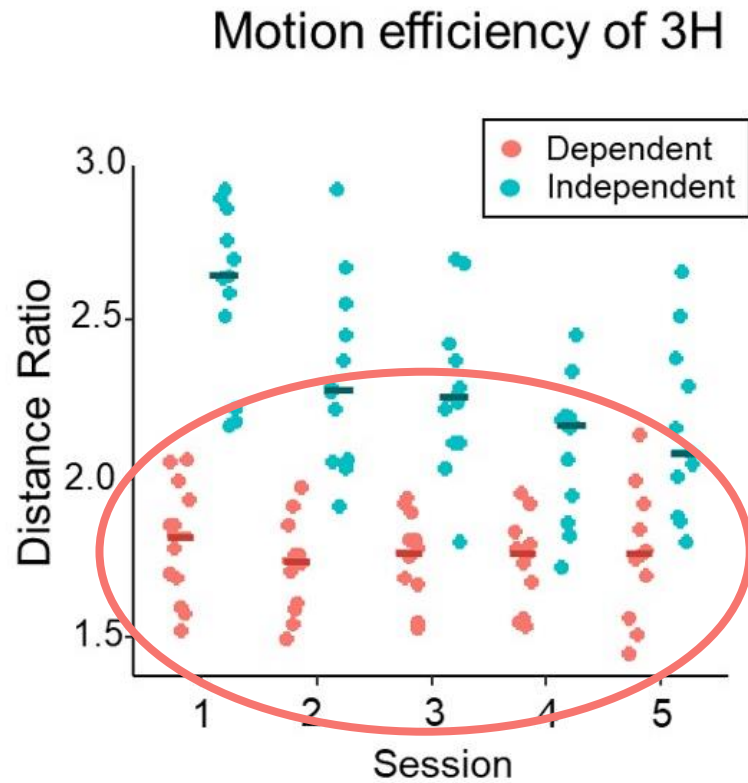
Motion efficiency of 3H





# RESULTS

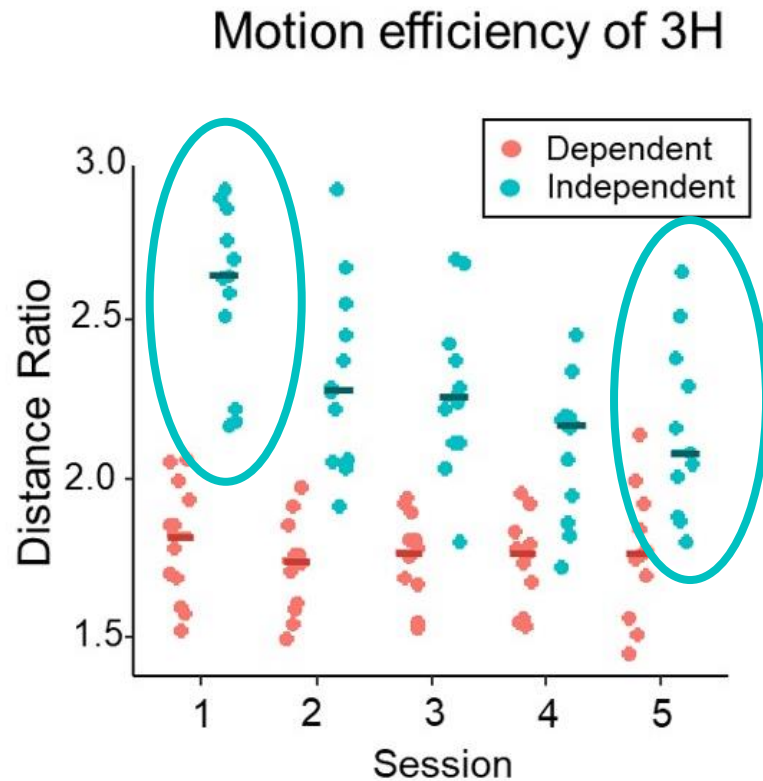
# Comparison - Performance



- More efficient for the Dependent Task

# RESULTS

# Comparison - Performance

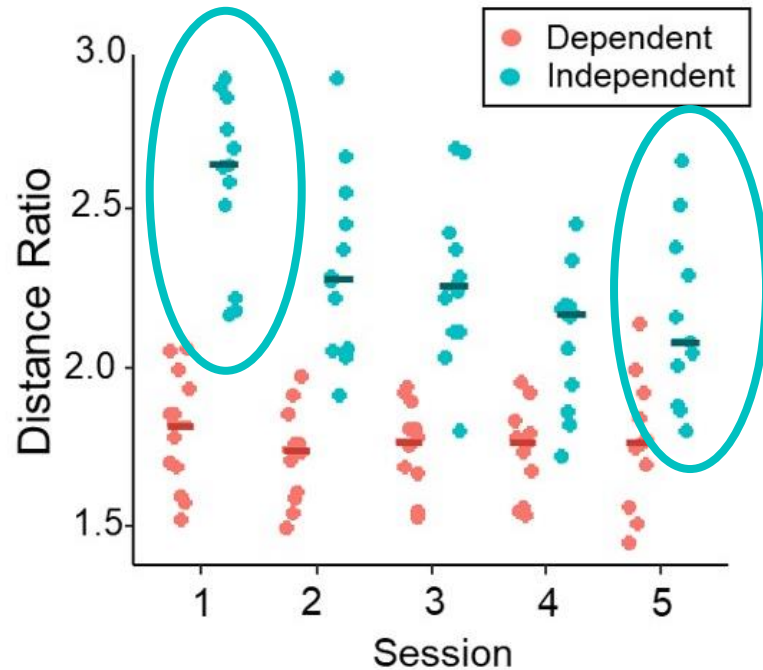


- More efficient for the Dependent Task
  - BUT improvement for the Independent Task

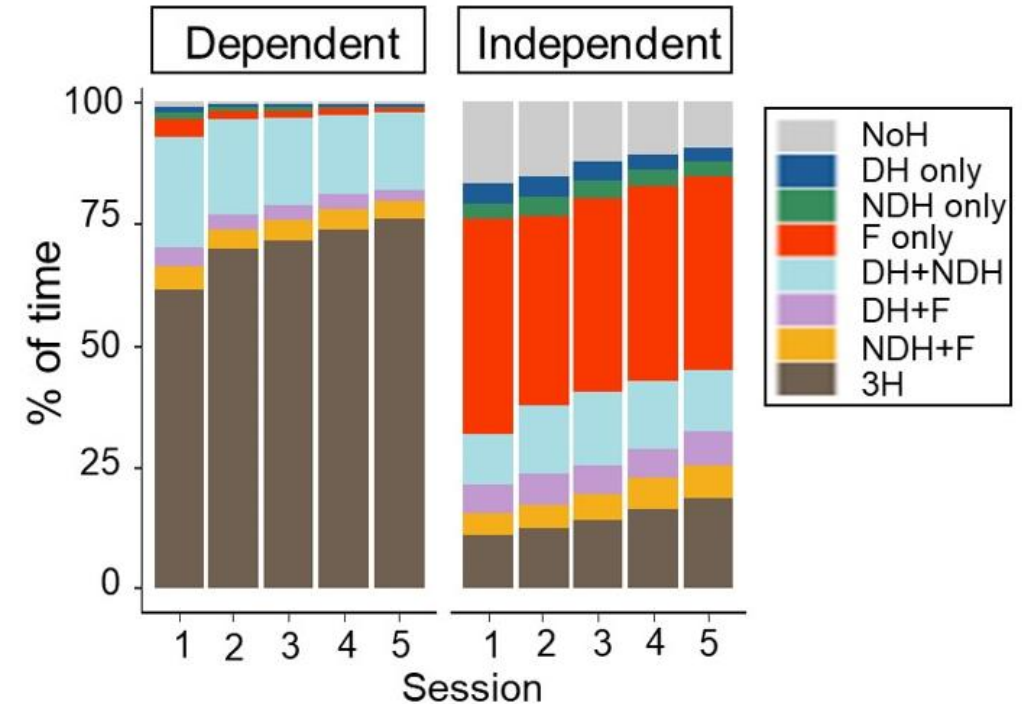
# RESULTS

# Comparison - Performance

Motion efficiency of 3H



Hand coordination

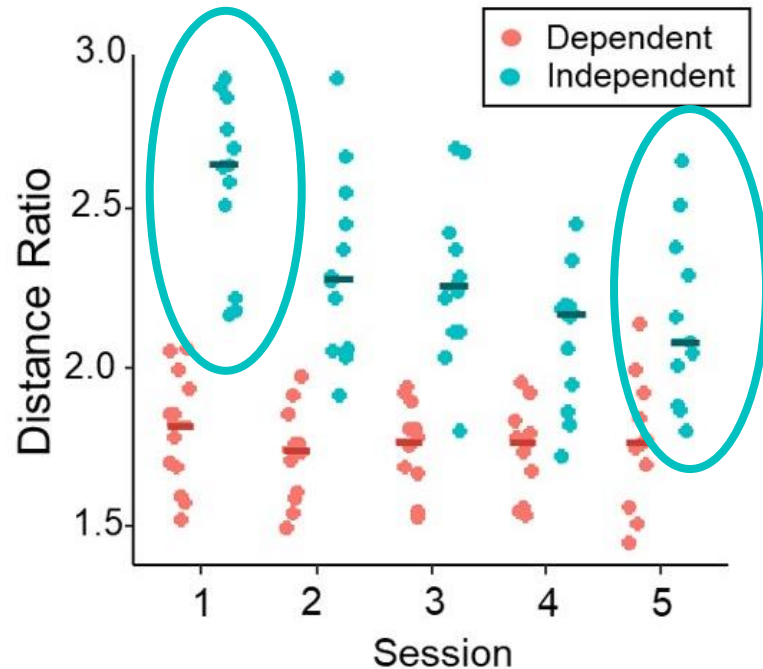


- More efficient for the Dependent Task
  - BUT improvement for the Independent Task

# RESULTS

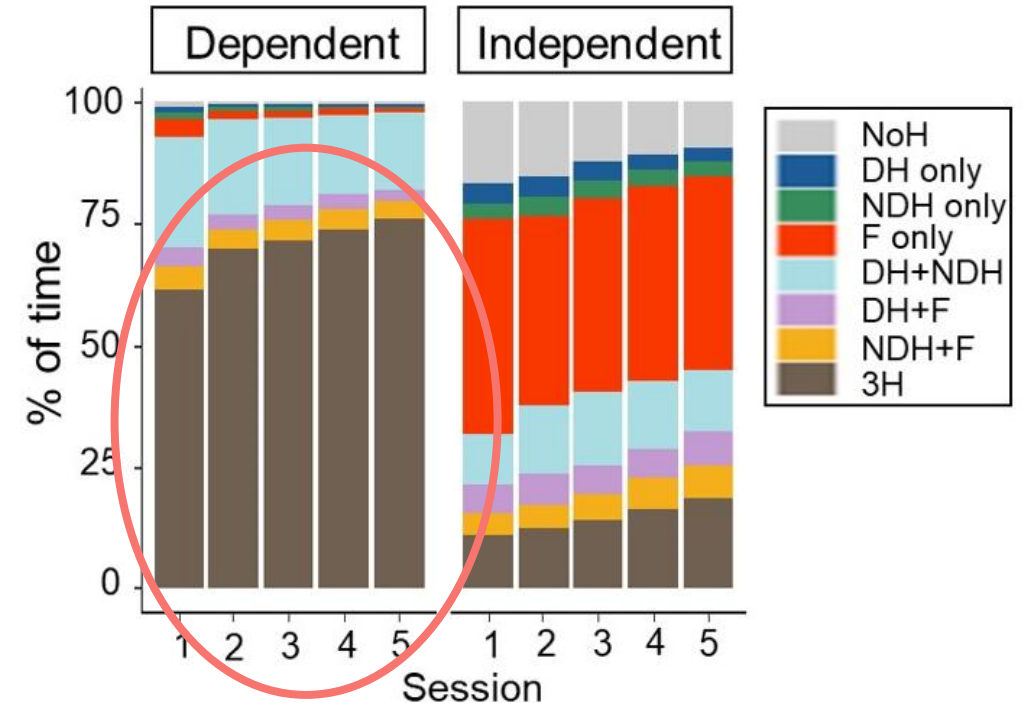
# Comparison - Performance

Motion efficiency of 3H



- More efficient for the Dependent Task
  - BUT improvement for the Independent Task

Hand coordination

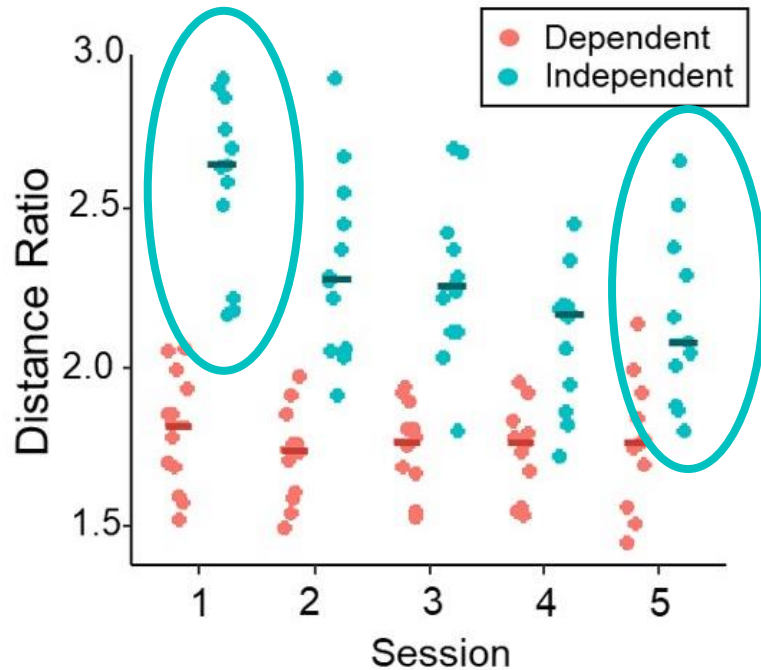


- More active trimanipulation for the Dependent Task

# RESULTS

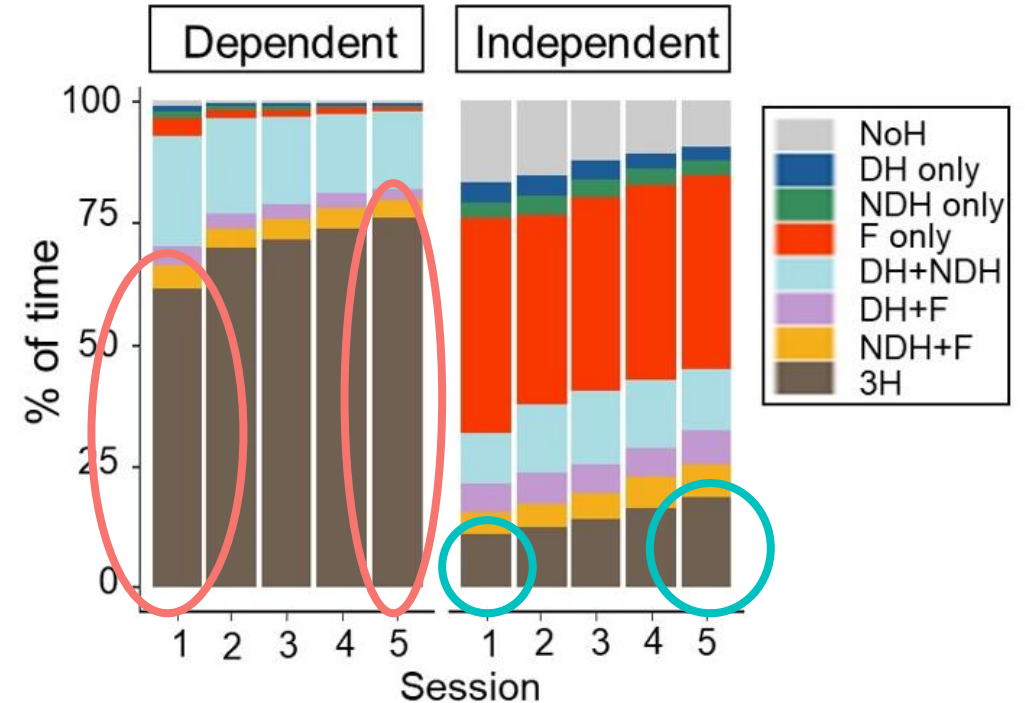
# Comparison - Performance

### Motion efficiency of 3H



- More efficient for the Dependent Task
  - BUT improvement for the Independent Task

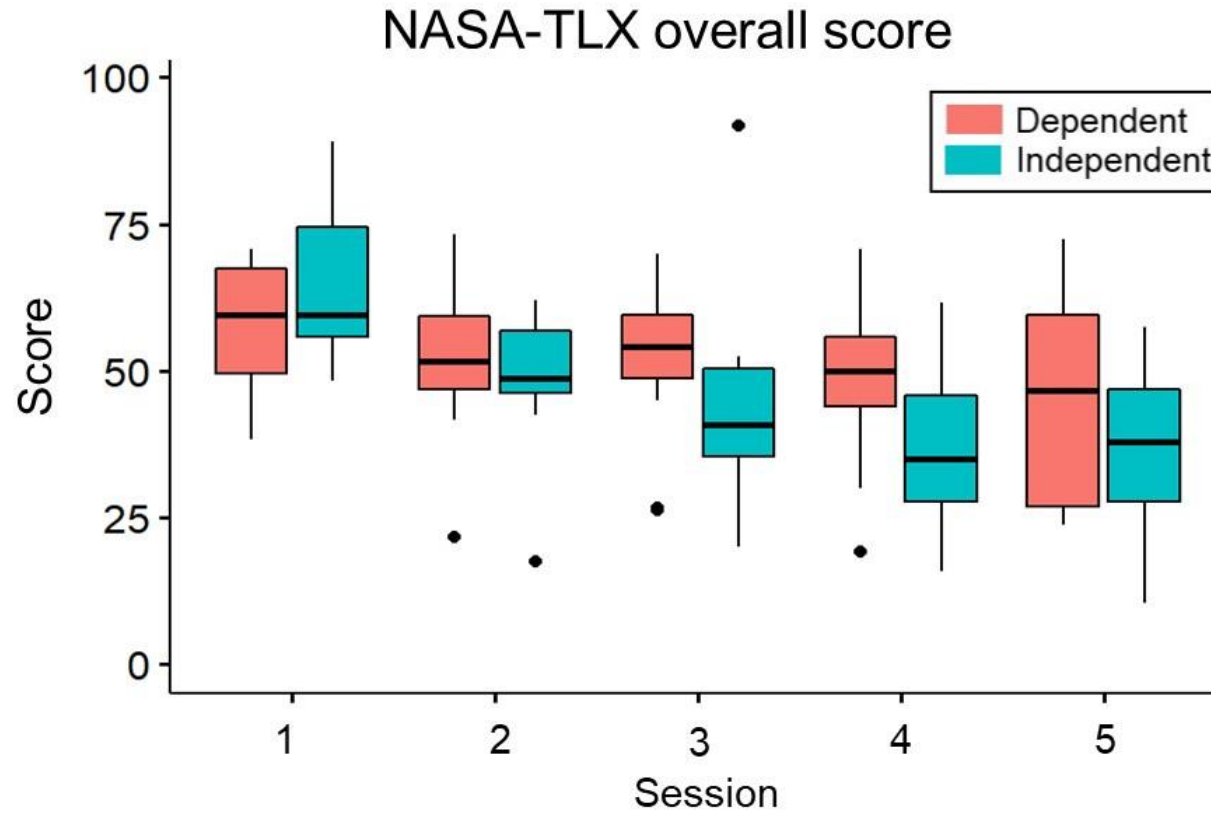
### Hand coordination



- More active trimanipulation for the Dependent Task
  - BUT improvement for both tasks

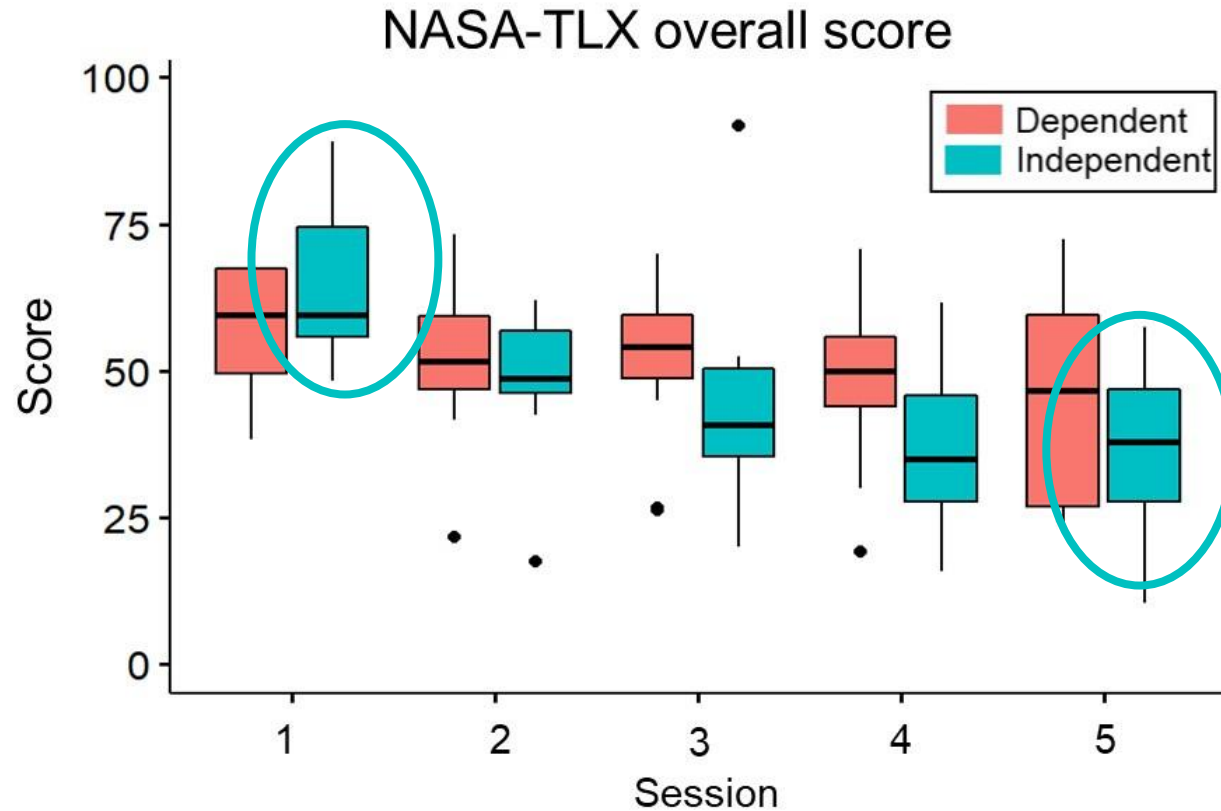
# RESULTS

## Comparison - Perception



# RESULTS

## Comparison - Perception



Independent task– The perceived workload decreased from Session 1 to 5

# Discussion



# Discussion

## Summary

- We studied the learning of different trimanual coordinations over 5 weeks
- The type of training impacts the performance and the motion characteristics
- Overall there is improvement with training
- The hands-foot coordination may be the main limiting factor, but it does improve with training

# Discussion

## Summary

- We studied the learning of different trimanual coordinations over 5 weeks
- The type of training impacts the performance and the motion characteristics
- Overall there is improvement with training
- The hands-foot coordination may be the main limiting factor, but it does improve with training

## Future work

- Expand the study of trimanual coordination to consider other possible control interfaces and tasks

Thank you for your time!

