

# Comparison of Human **Trimanual Performance** between Independent and Dependent Multiple-limb Training Modes

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Picture: Stelarc photographed by K. Oki

## Traditional



Picture: Curry Health Network, Gold Beach, Oregon

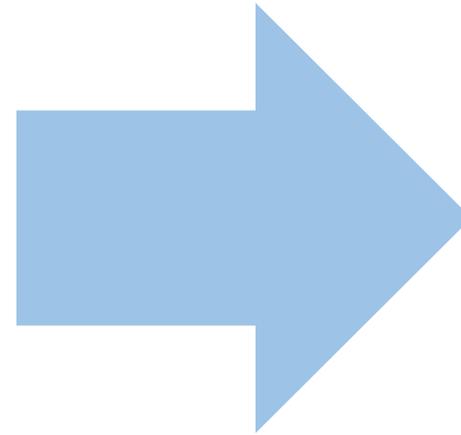
## Traditional



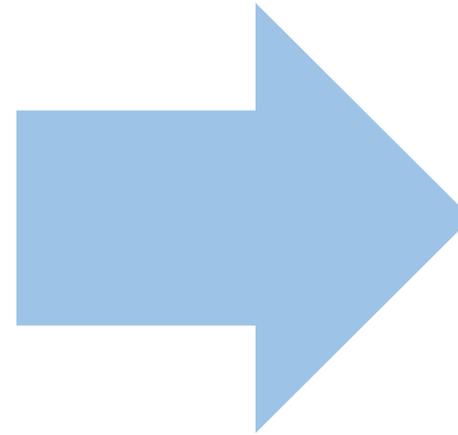
- Miscommunication within a team leads to errors
- Time to learn how to work with each new partner
- Difference in views between people

Picture: Curry Health Network, Gold Beach, Oregon

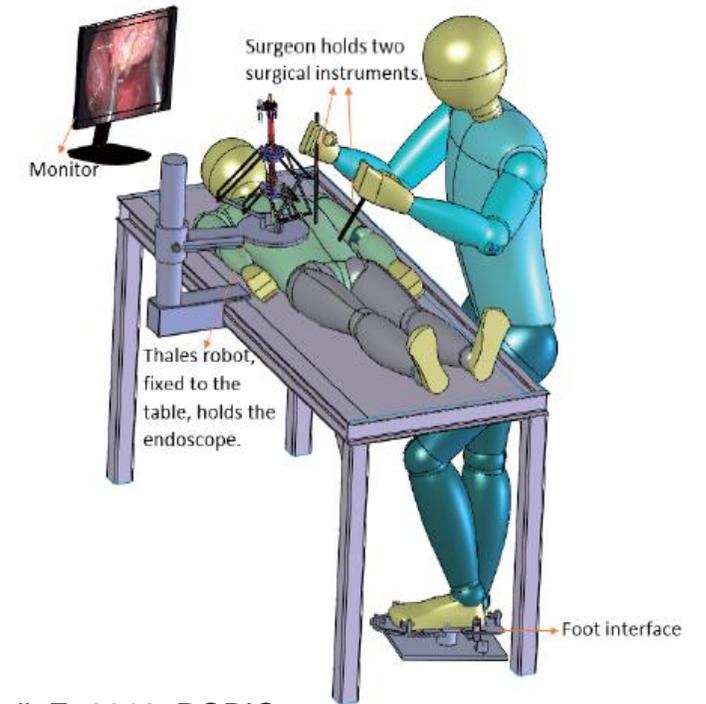
Traditional



Traditional



Augmented

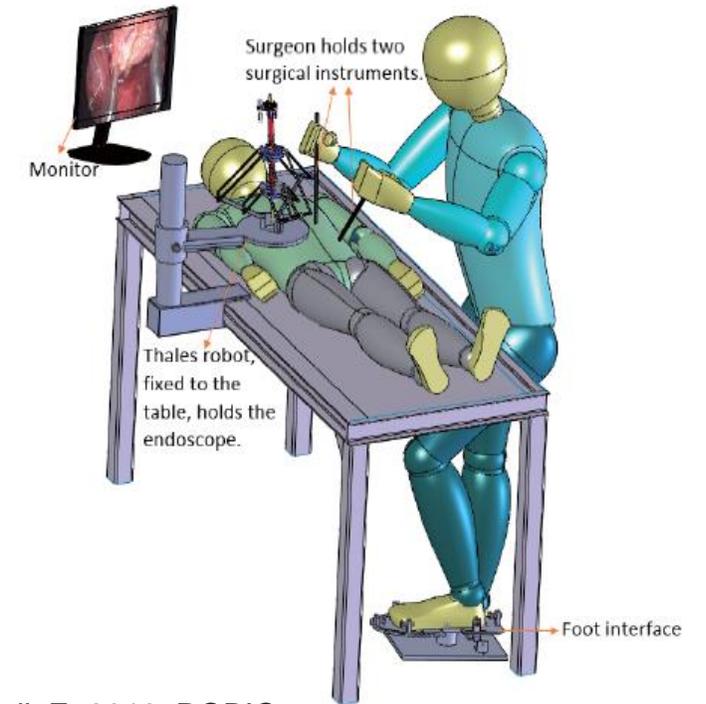


Schematic : Abdi, E. 2018, ROBIO

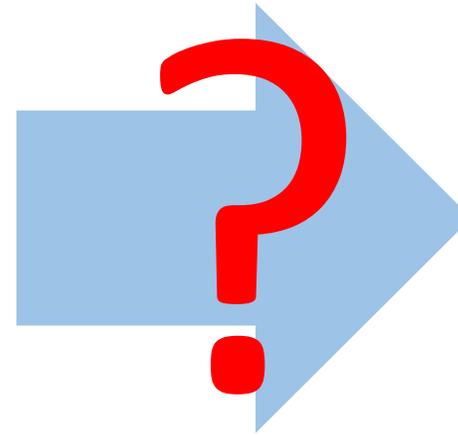
Traditional



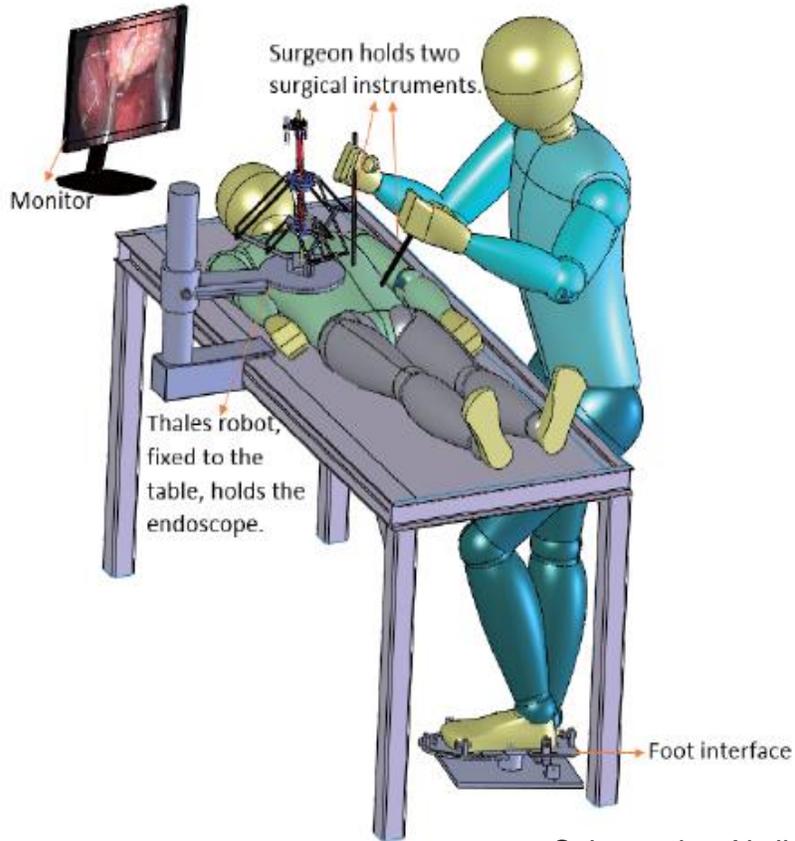
Augmented



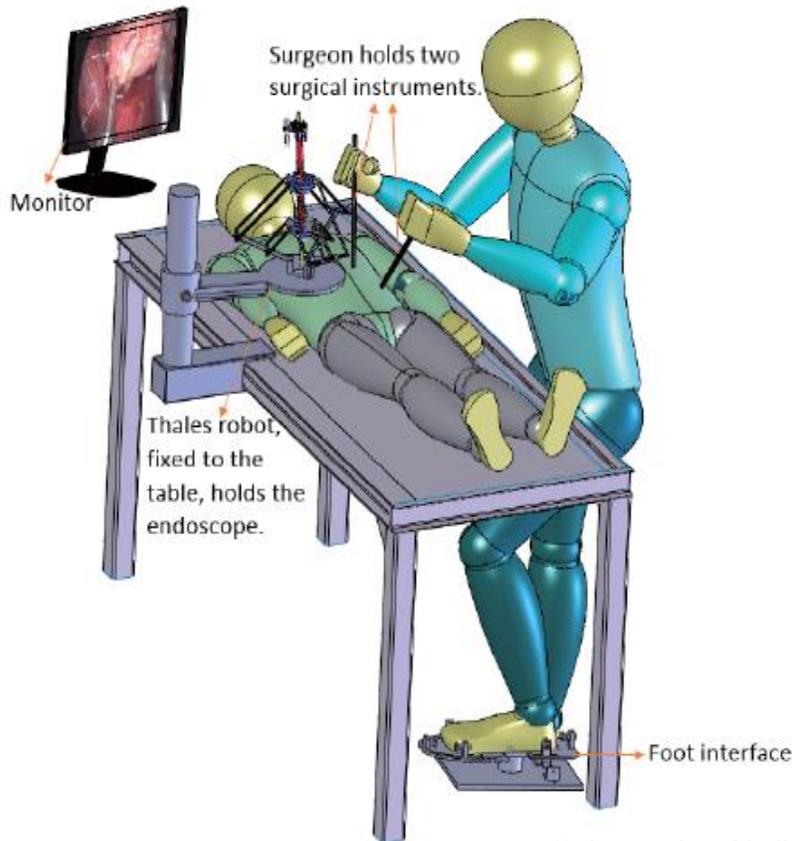
Schematic : Abdi, E. 2018, ROBIO



An extra 'hand' is extra... **In theory**



Schematic : Abdi, E. 2018, ROBIO



Schematic : Abdi, E. 2018, ROBIO

- Is it sufficient to train the foot alone?
- Is it necessary to train on the whole task? (hands and foot)
- Is it possible to train on subtasks or different tasks?



Picture: Sony Pictures, 2004



Picture: Sony Pictures, 2004

- How best to train a user to perform augmentation?
  - Can trimanual skills be transferred from one task to another ?



Picture: Sony Pictures, 2004

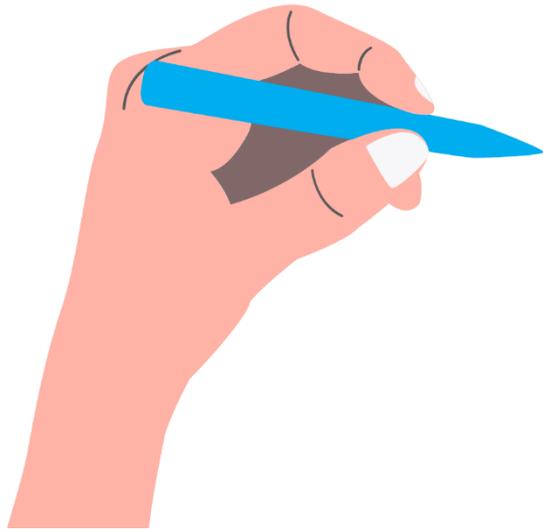
- How best to train a user to perform augmentation?
  - Can trimanual skills be transferred from one task to another ?
- What tasks is such augmentation best suited to?
- Can a human user control additional independent degrees of freedom without sacrificing their natural performance?

How best to train a user to perform augmentation?

→ Can trimanual skills be transferred from one task to another ?

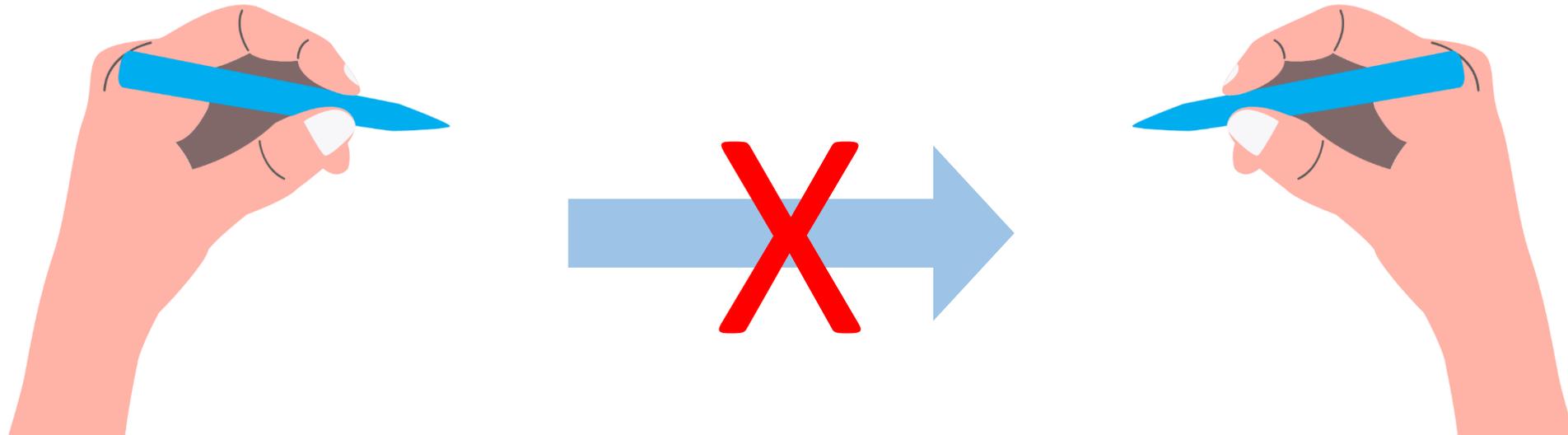
How best to train a user to perform augmentation?

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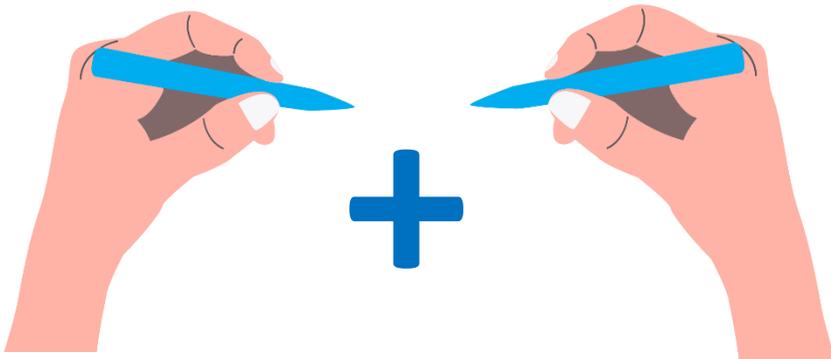


How best to train a user to perform augmentation?

→ Can trimanual skills be transferred from one task to another ?

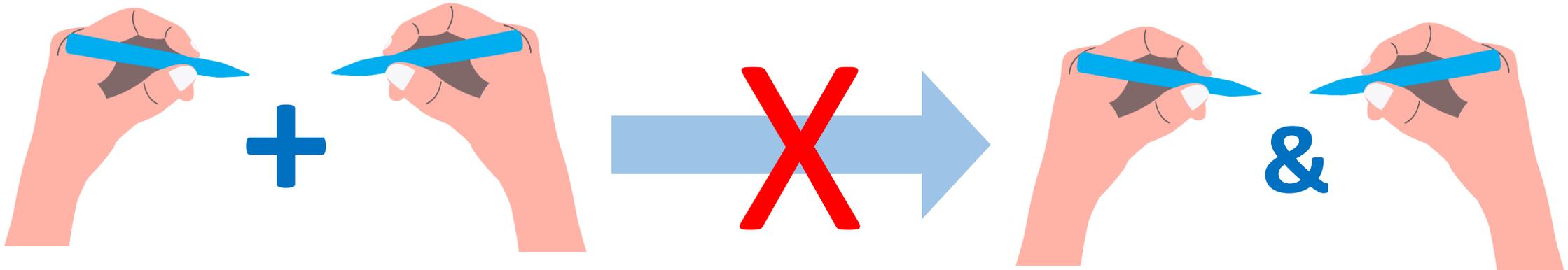
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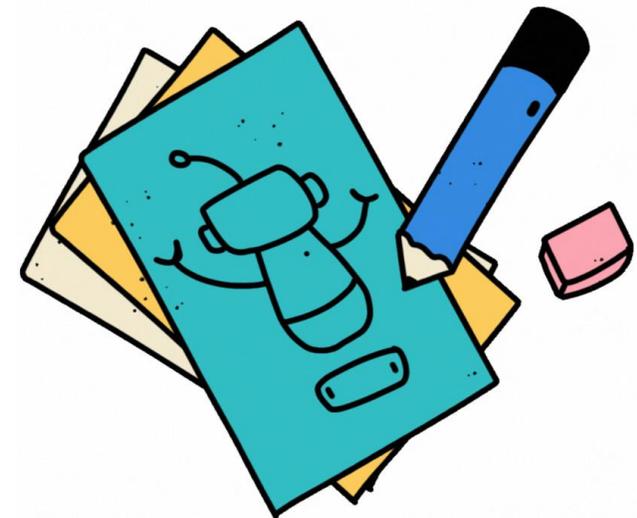
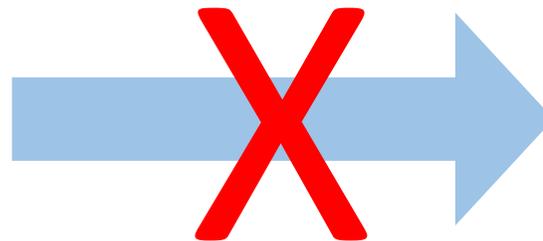
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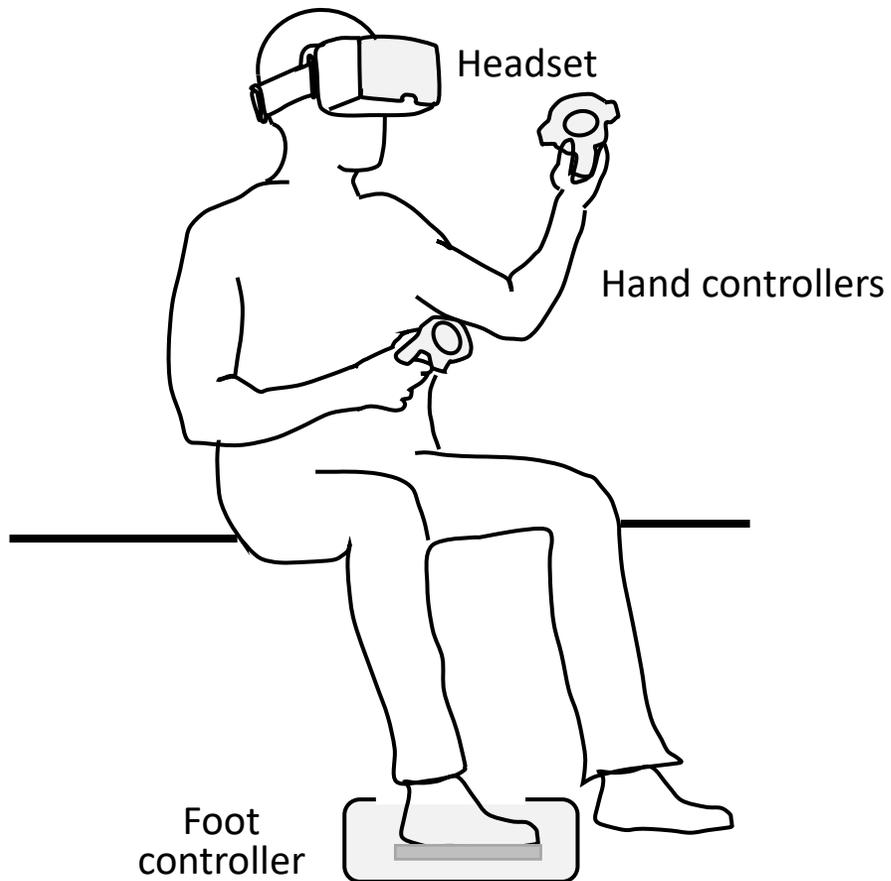


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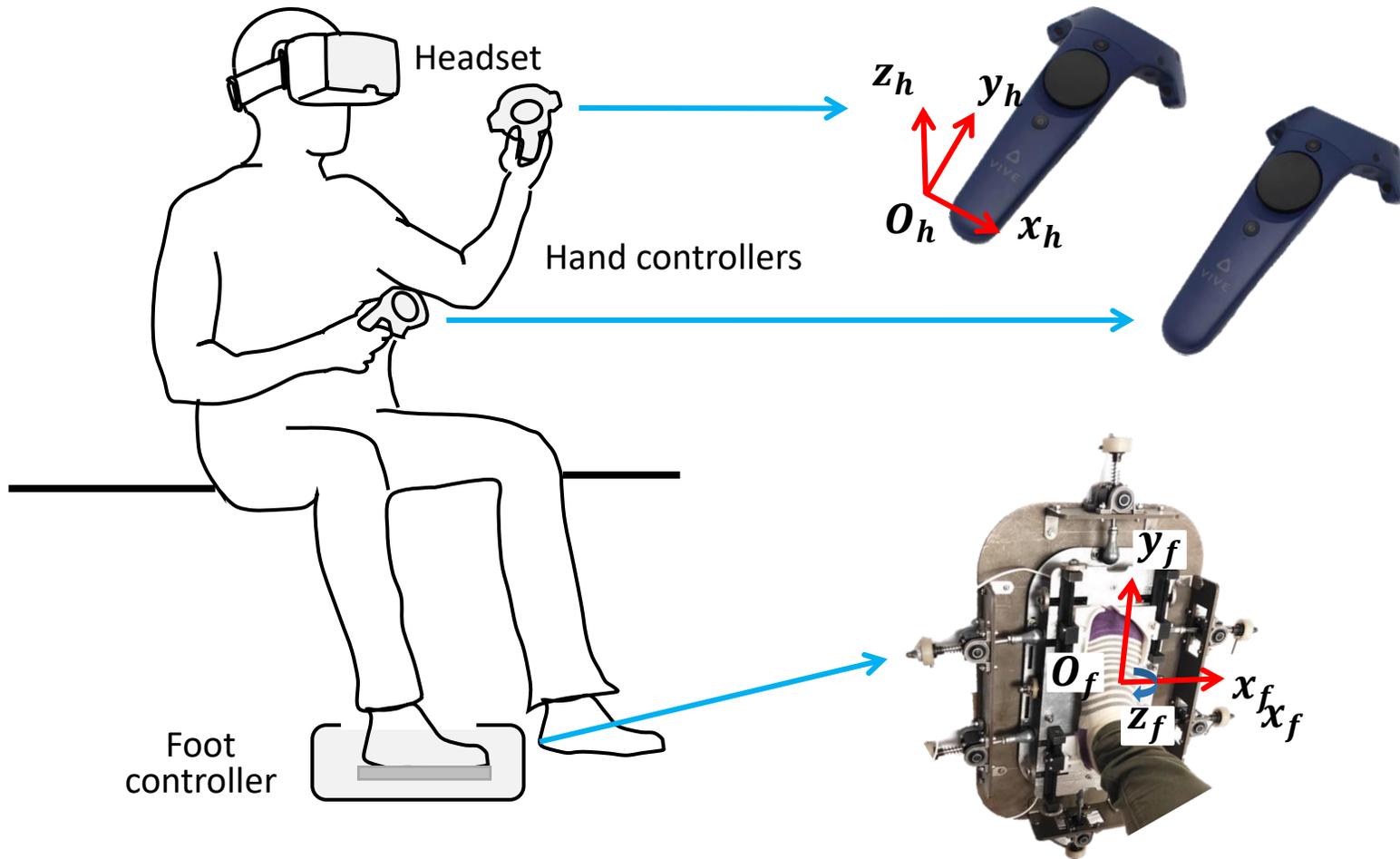


# Experimental Setup

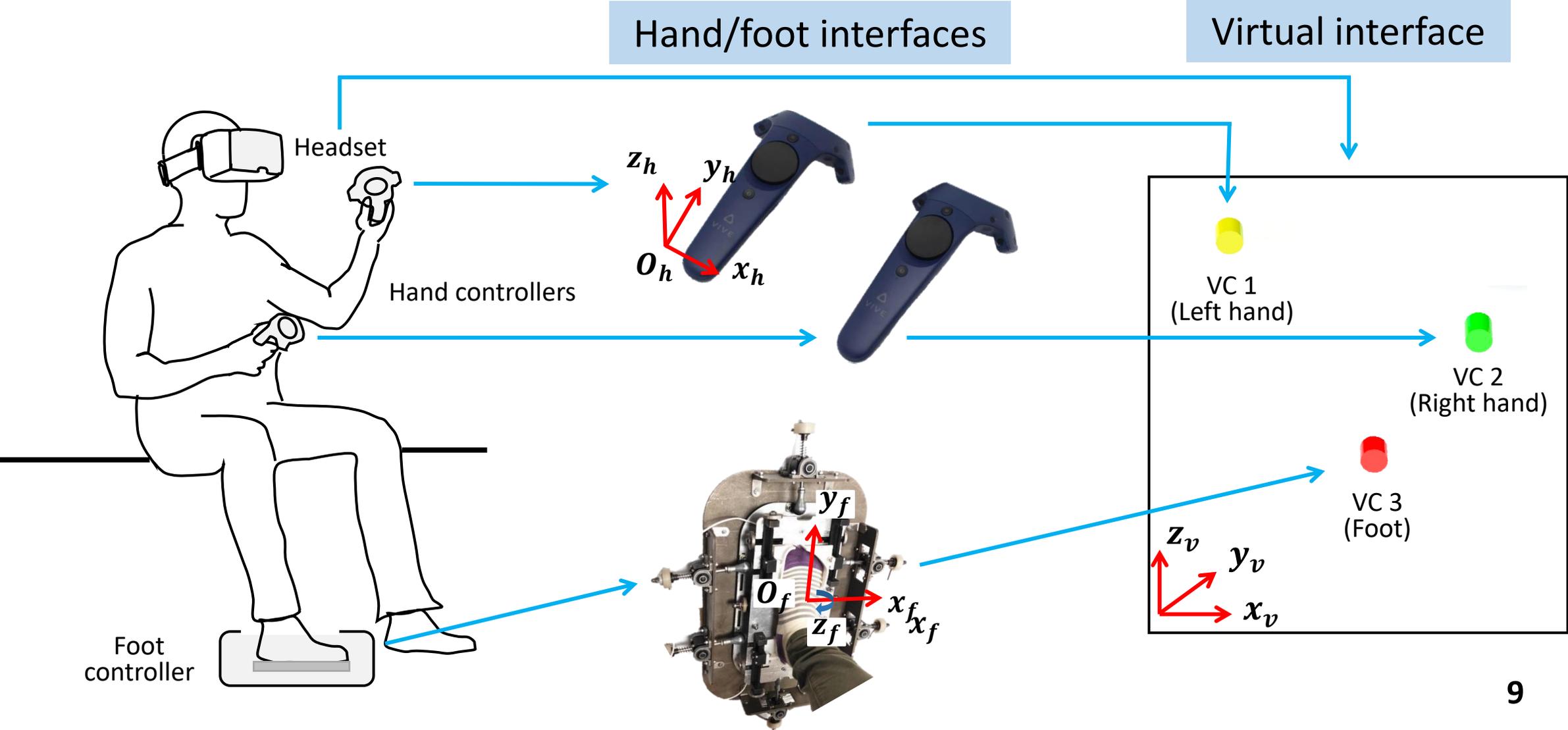


# Experimental Setup

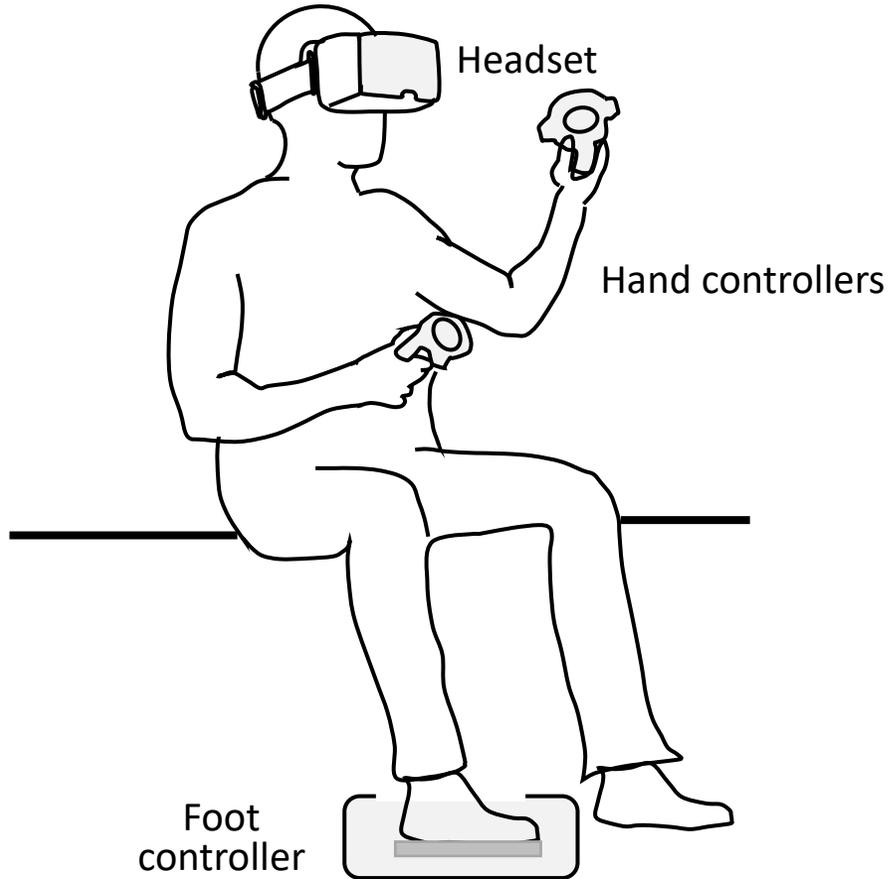
## Hand/foot interfaces



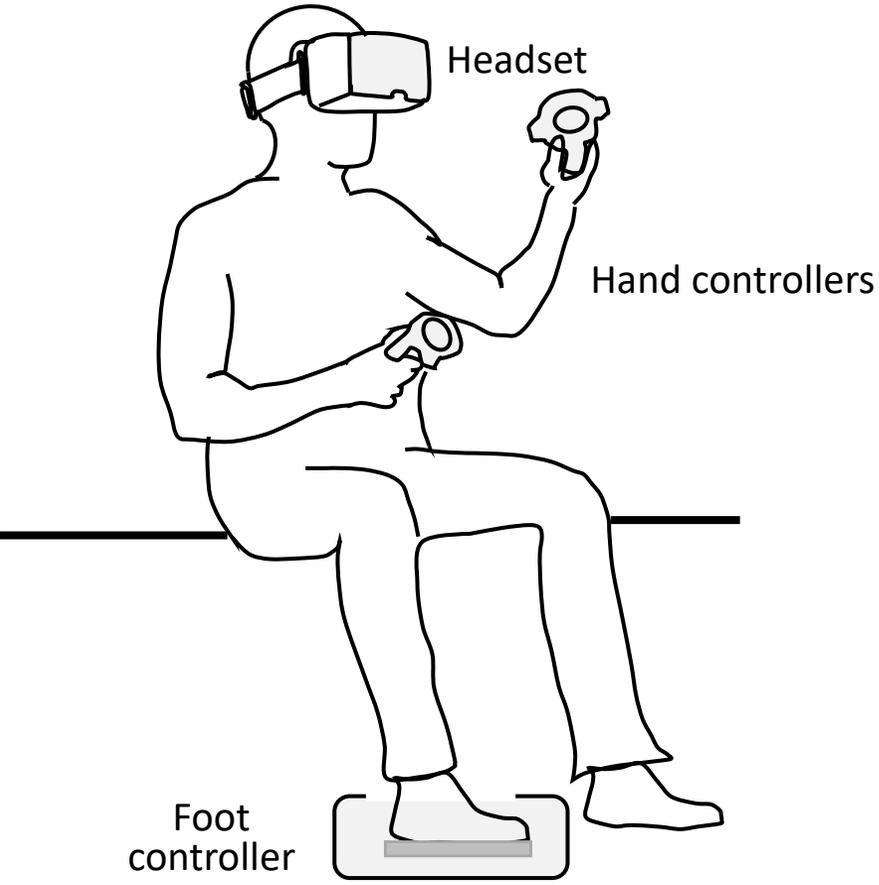
# Experimental Setup



# Training Tasks



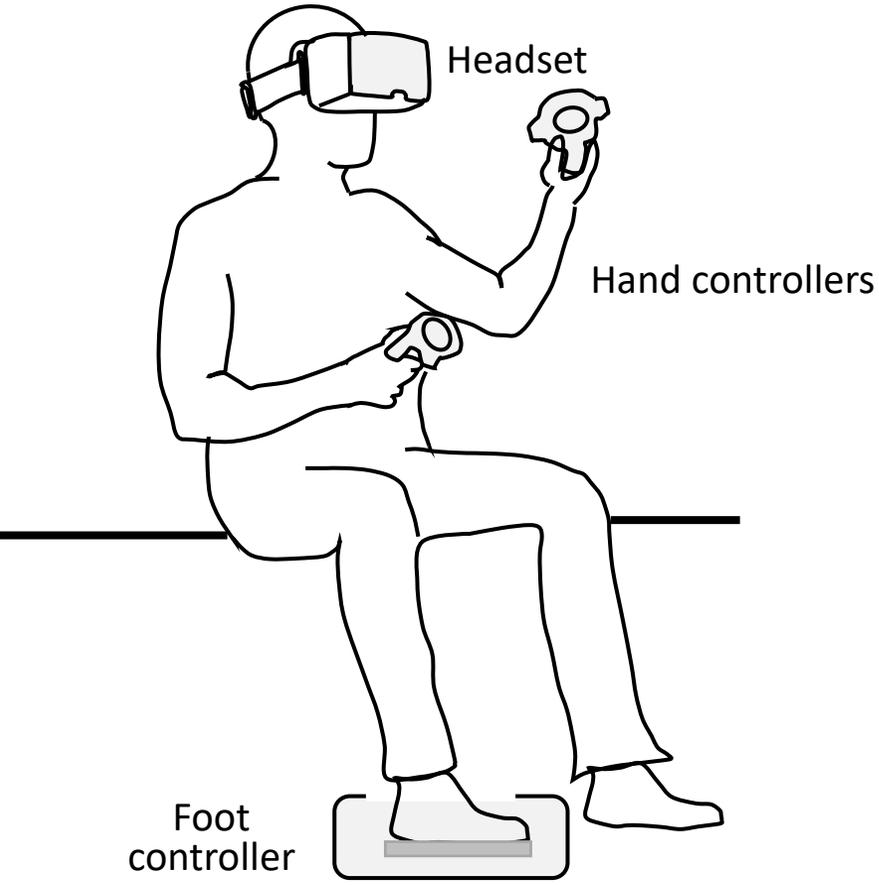
# Training Tasks



Independent

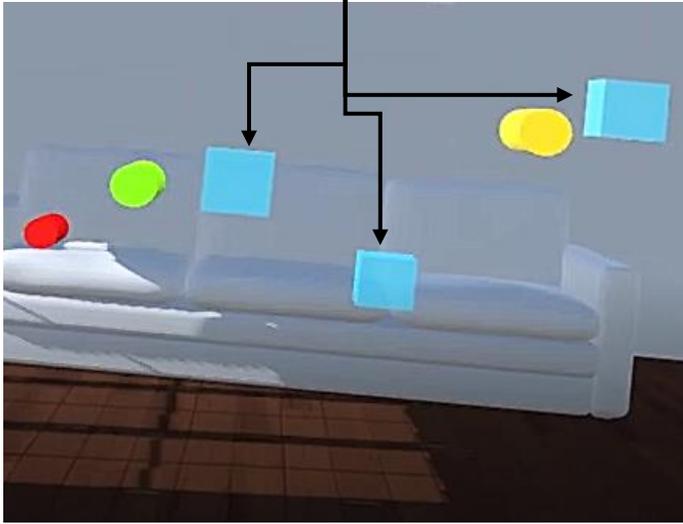
Dependent

# Training Tasks



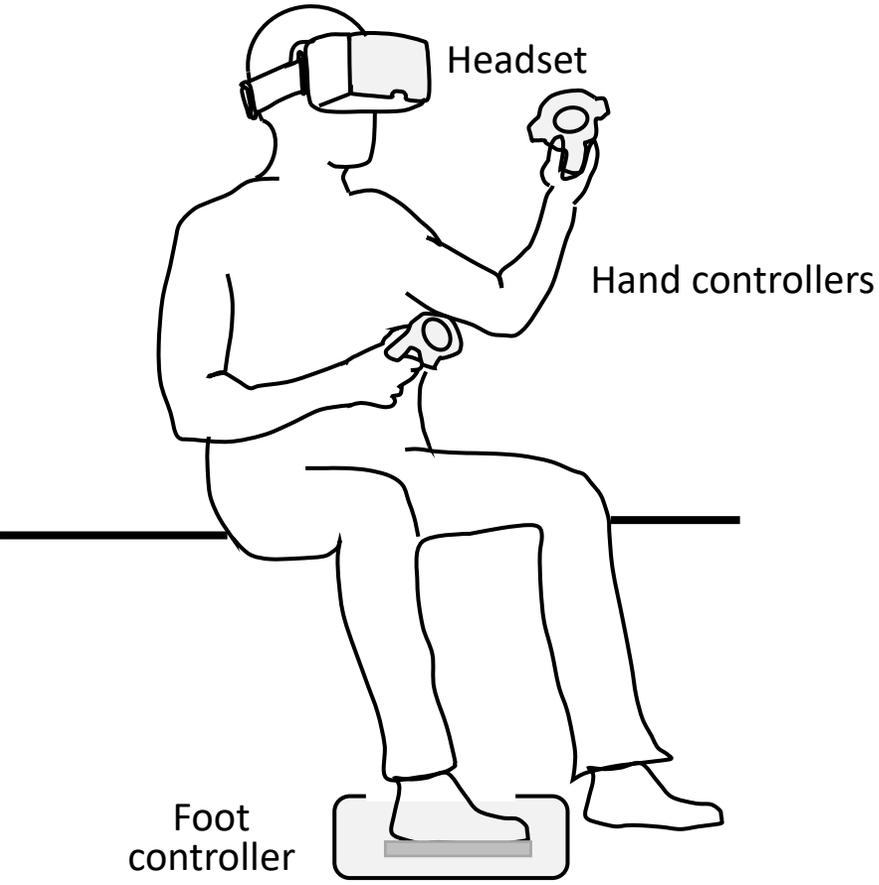
## Independent

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



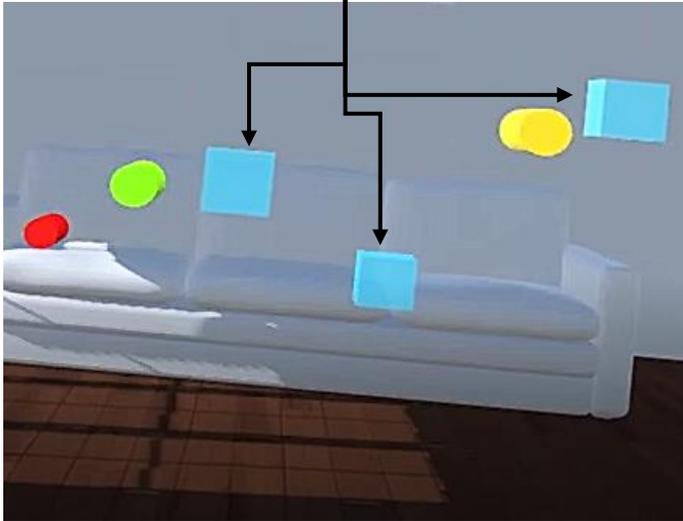
## Dependent

# Training Tasks



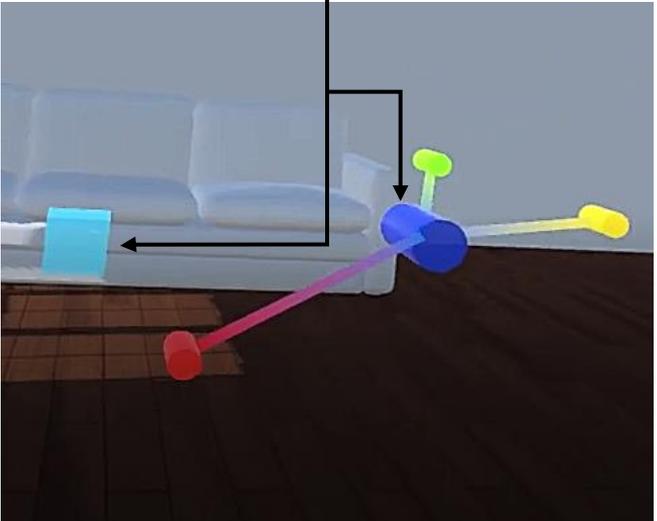
## Independent

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

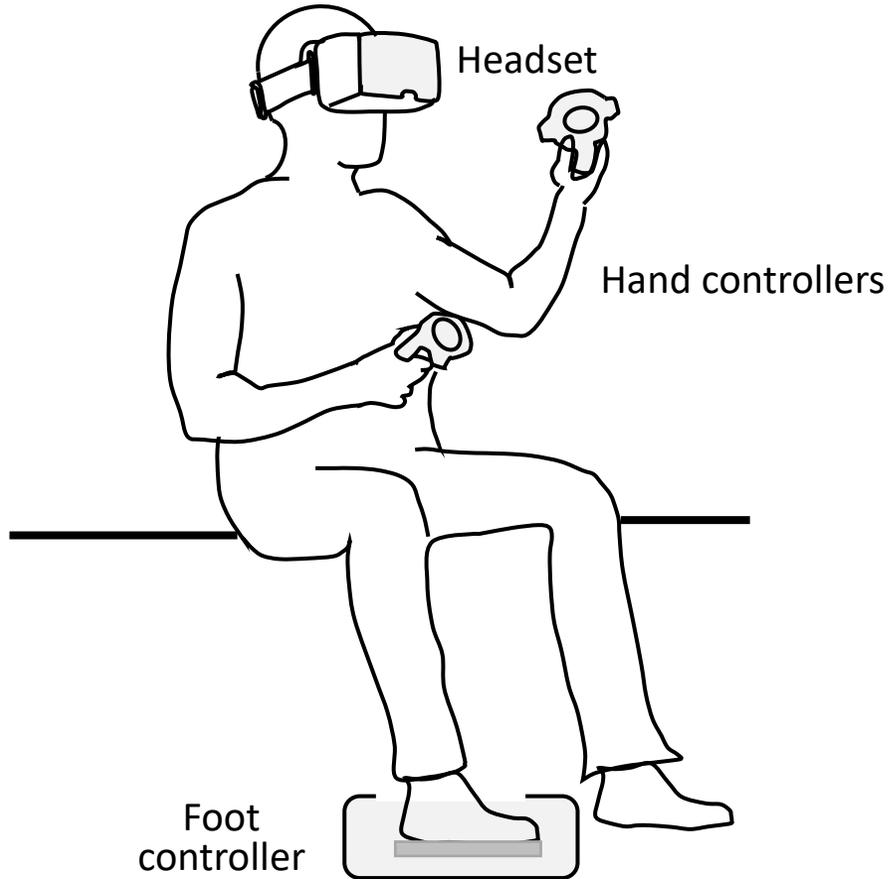


## Dependent

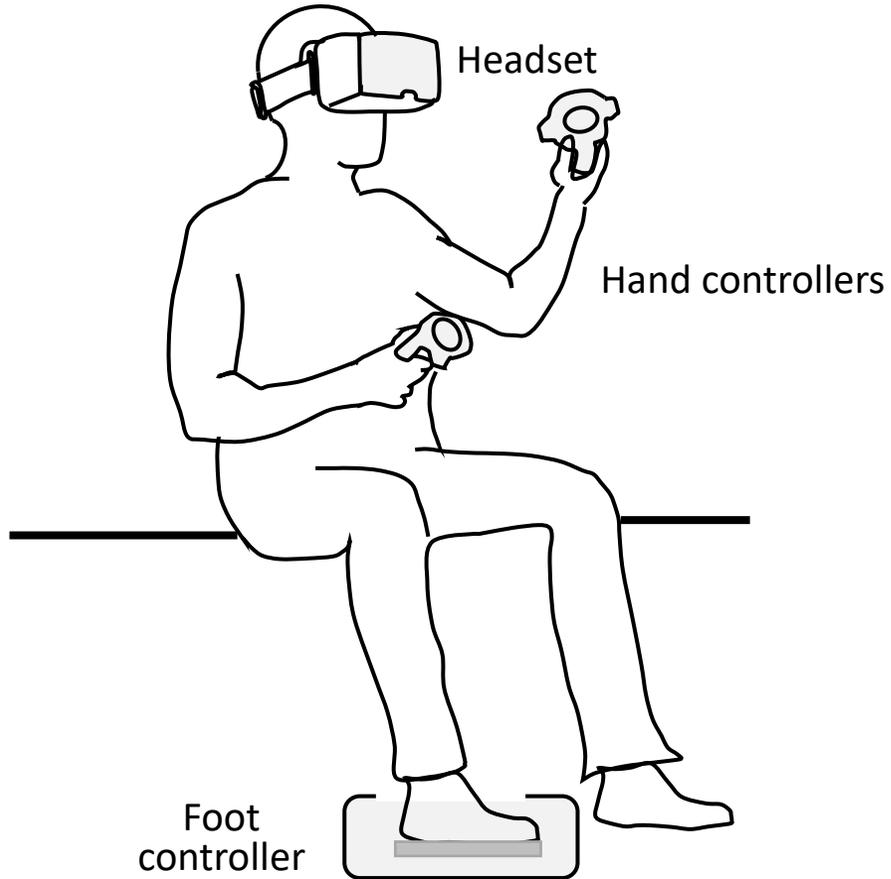
The target must be reached by the cursor COM



# Evaluation Task

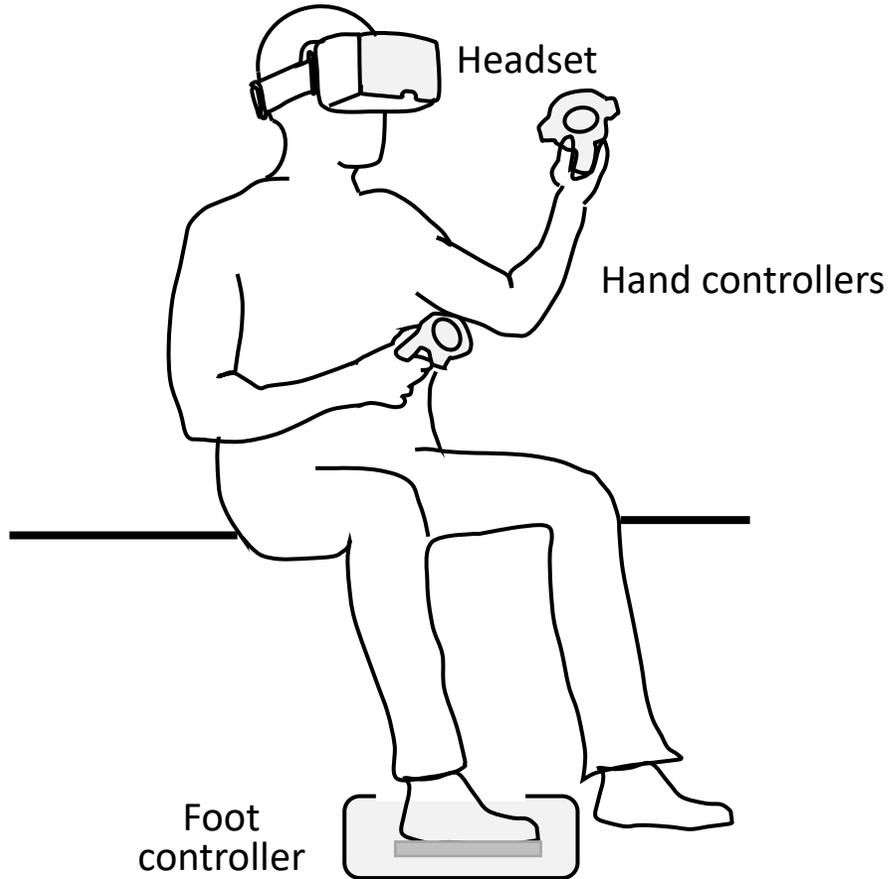


# Evaluation Task



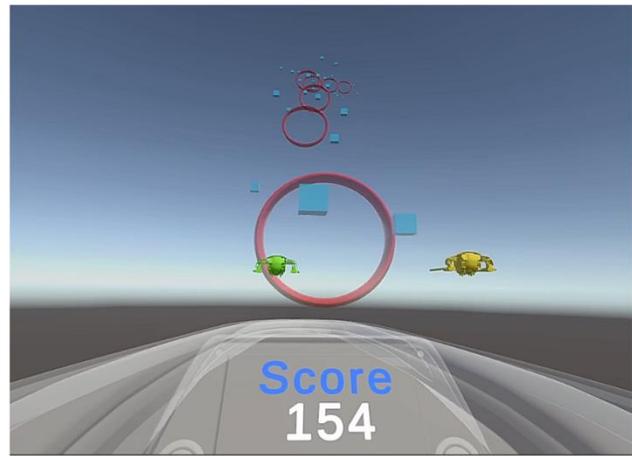
Spaceship

# Evaluation Task



## Spaceship

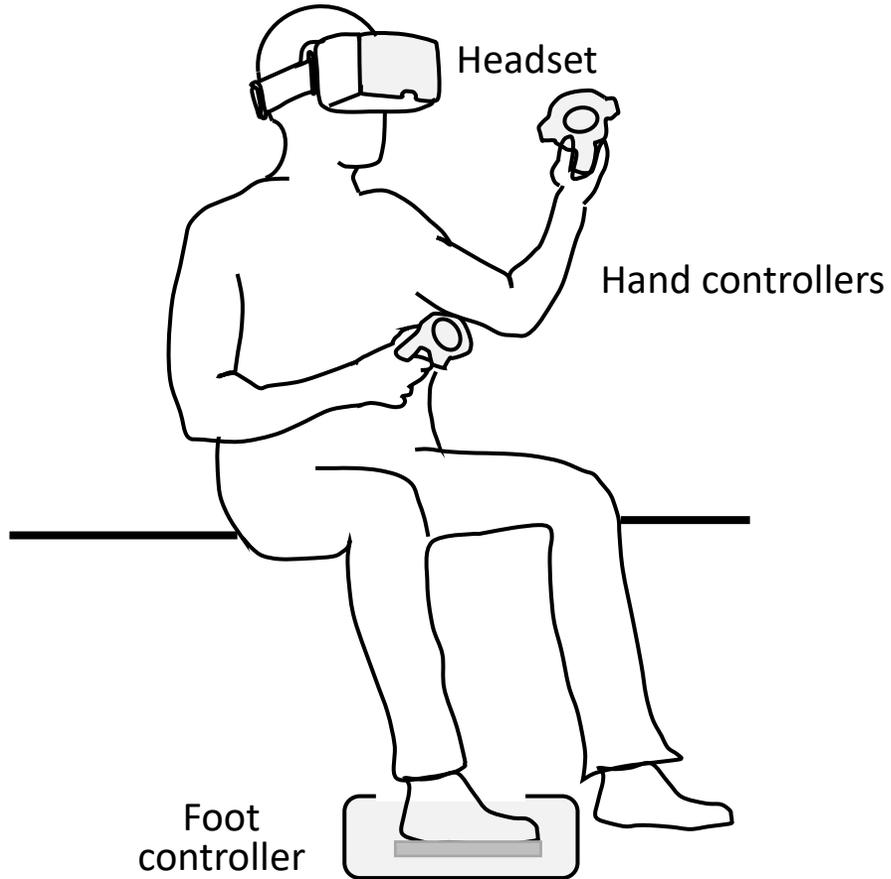
The user controls drones using the hands



The user is sitting in a spaceship controlled using the foot

Hands		Foot	
Left	Right		
			Cursor
			Target
1		5	Points

# Evaluation Task

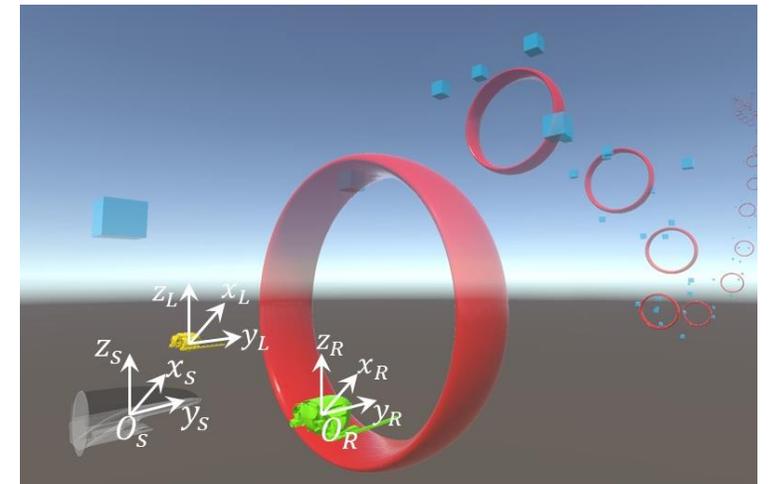


## Spaceship

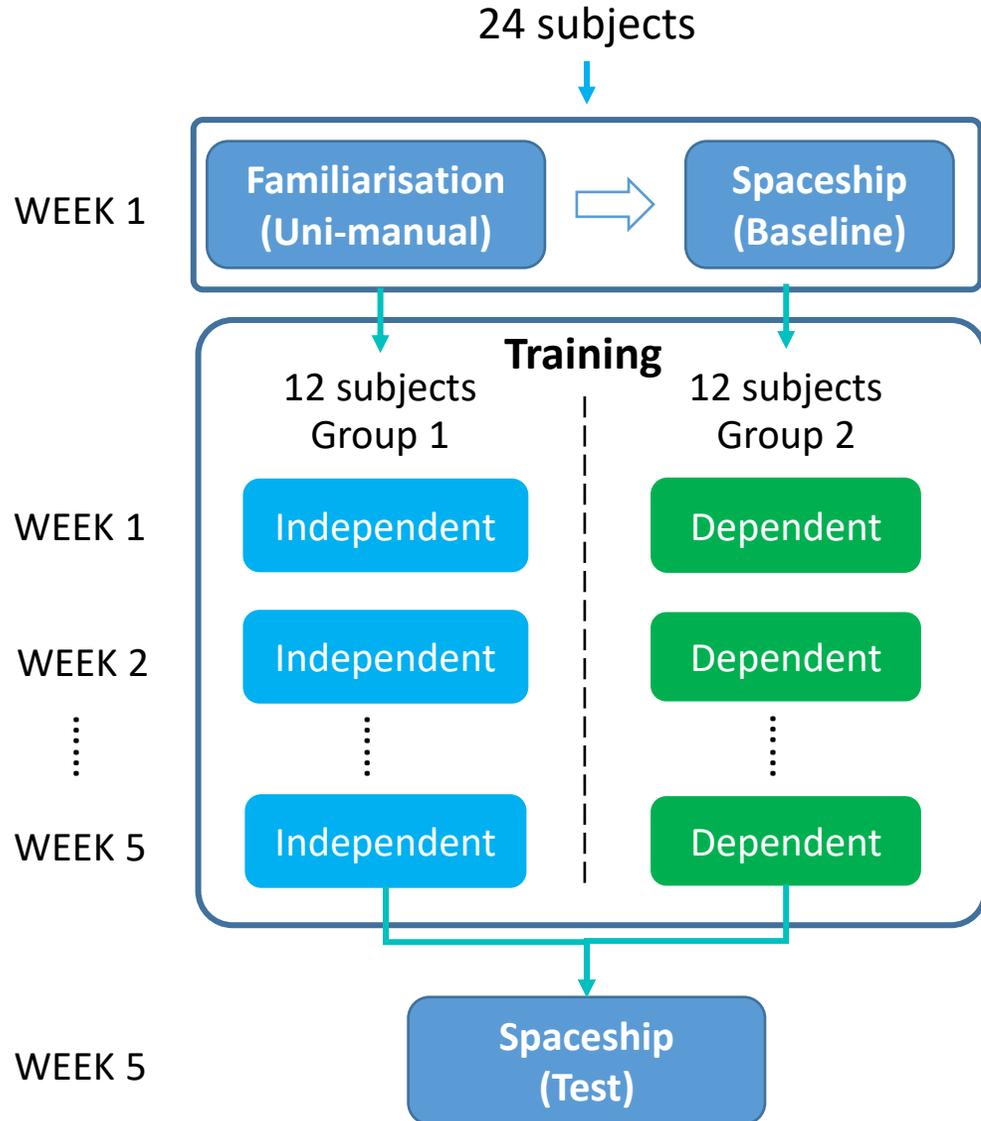
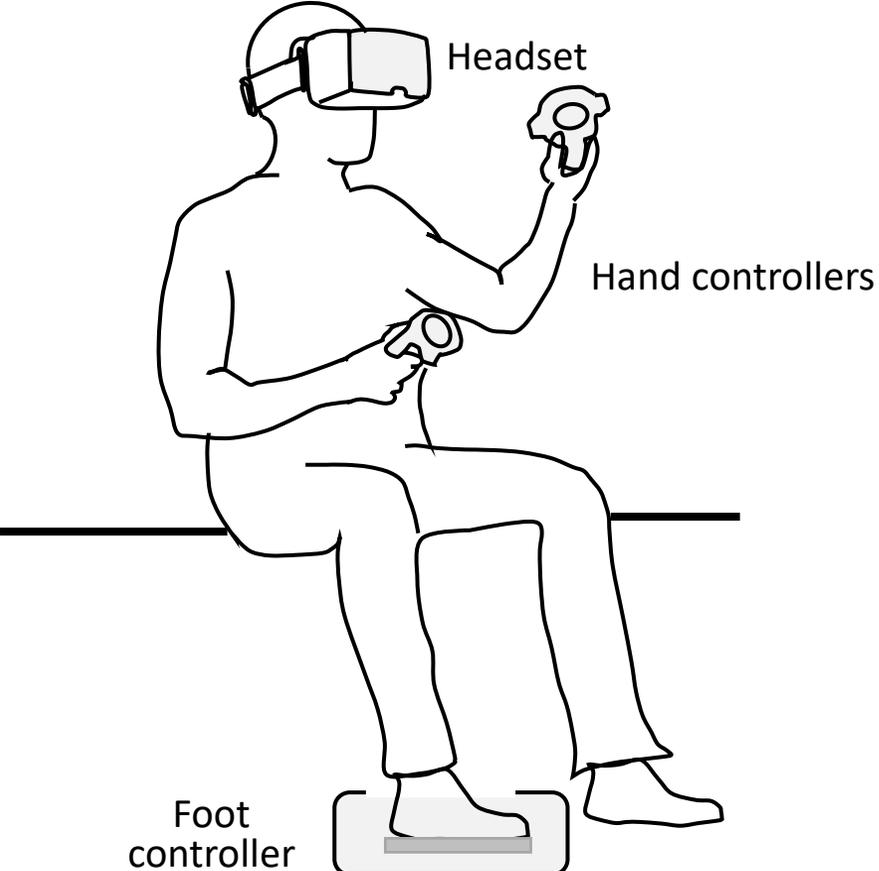
The user controls drones using the hands



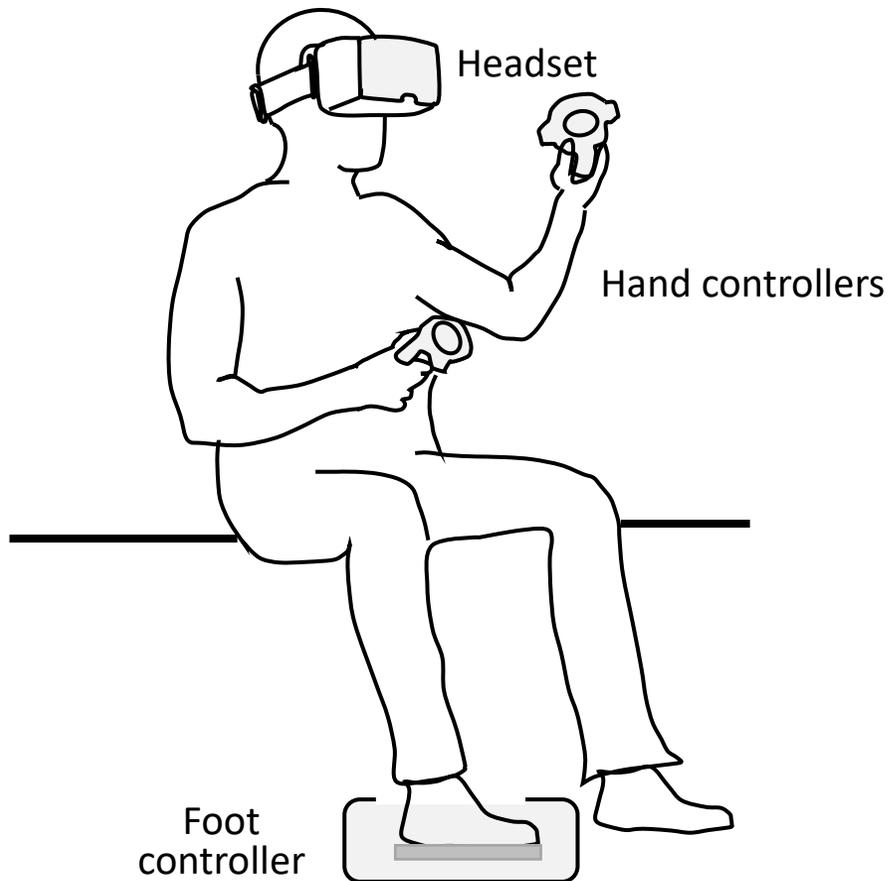
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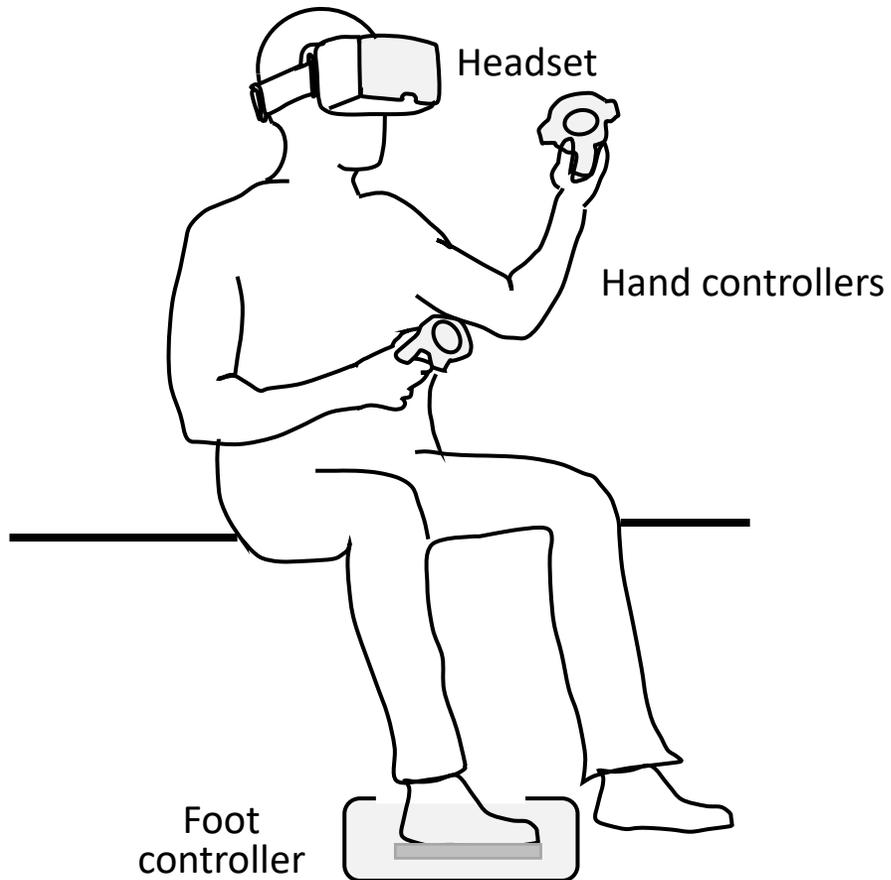
# Protocol



# Metrics



# Metrics

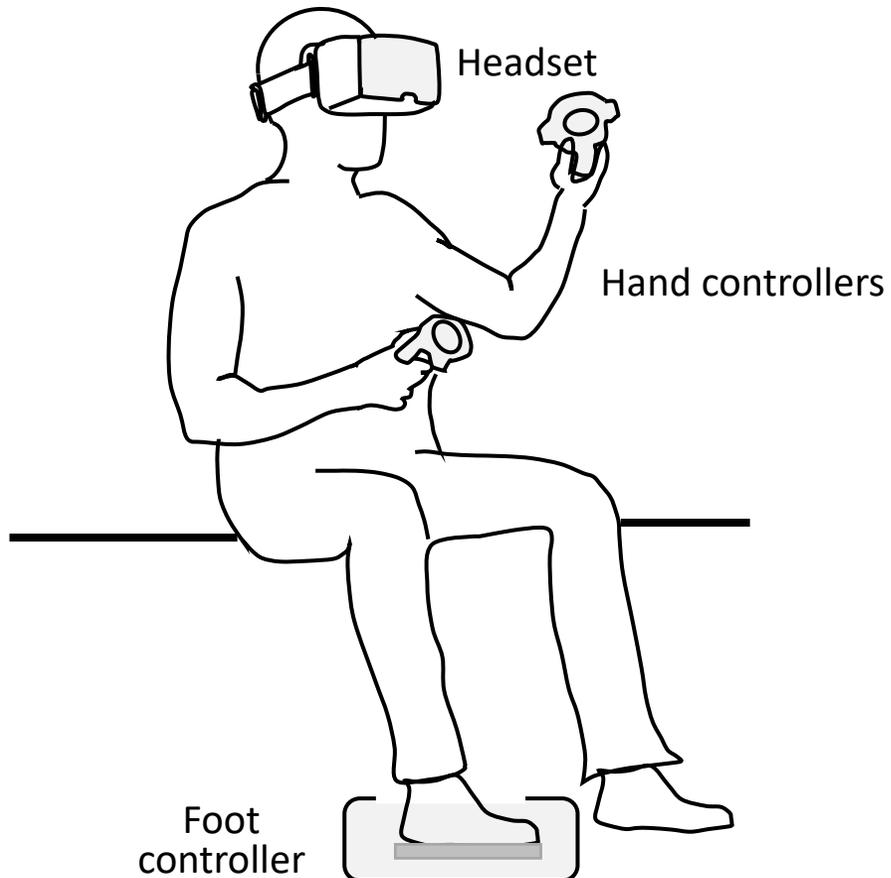


Third Hand

All Hands

# Metrics

## Third Hand



- Performance  
→ Number of gates crossed
- Motion smoothness  
→ SPARC

## All Hands

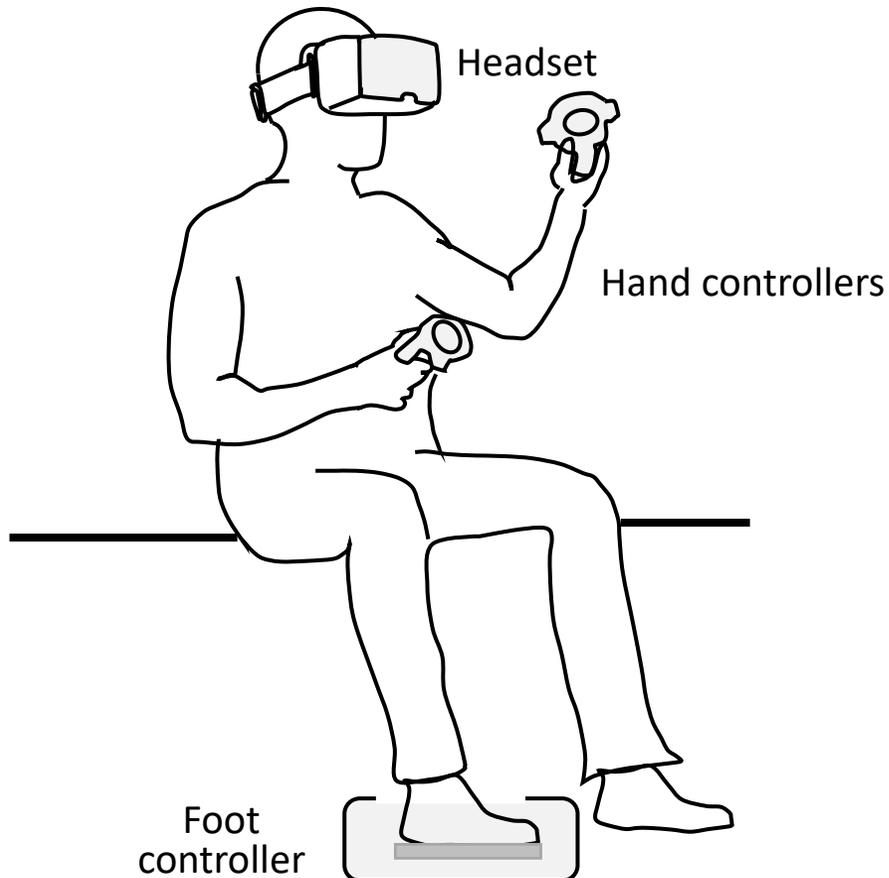
# Metrics

## Third Hand

- Performance
  - ➔ Number of gates crossed
- Motion smoothness
  - ➔ SPARC

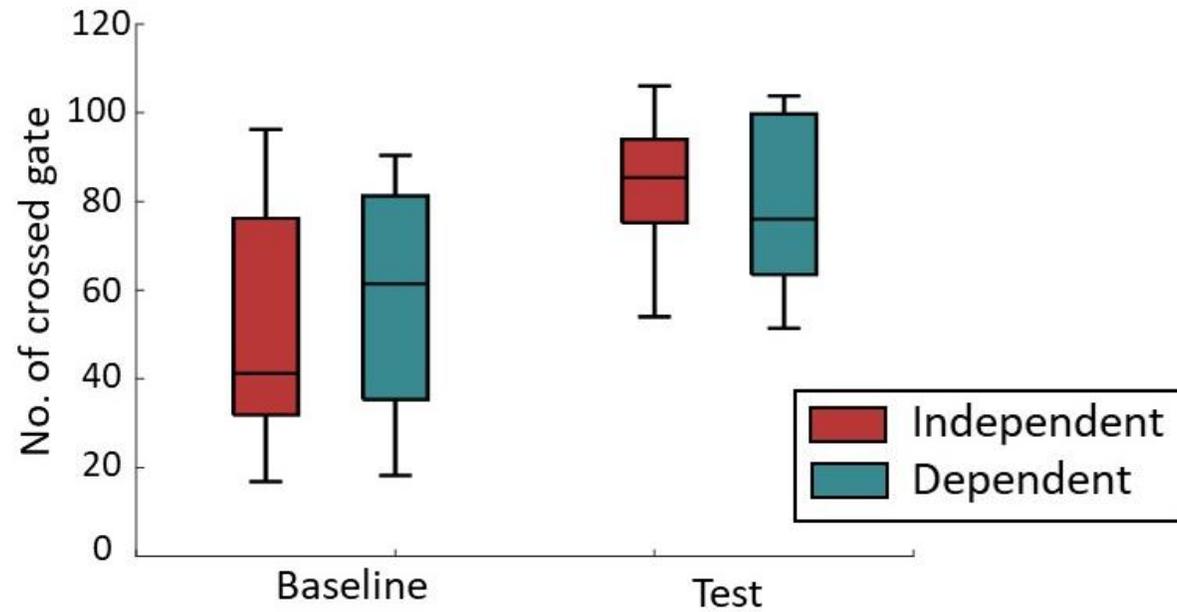
## All Hands

- Performance
  - ➔ Weighted score
- Coordination
  - ➔ Number of hand targets reached for each gate passed

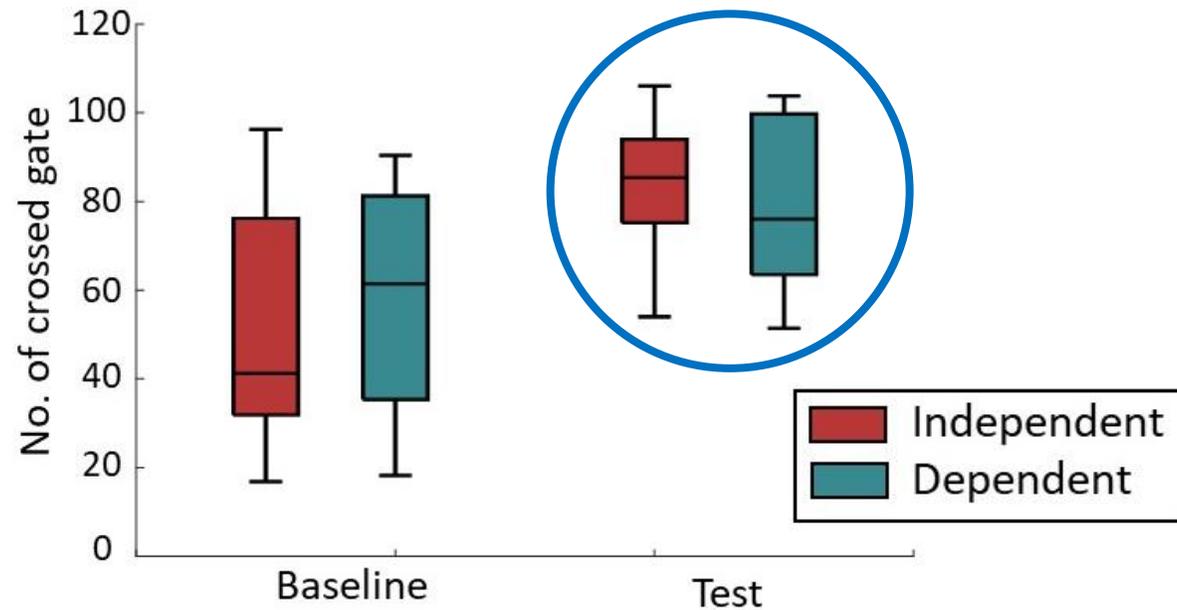




## Performance



## Performance

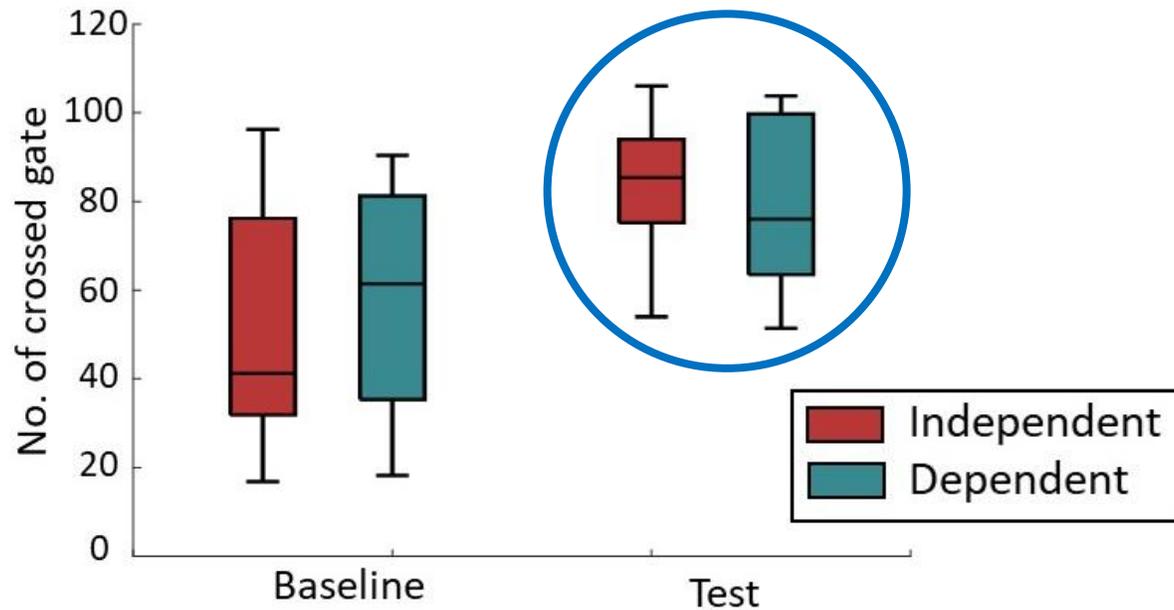


- Higher number of gates crossed
- The training task has no influence

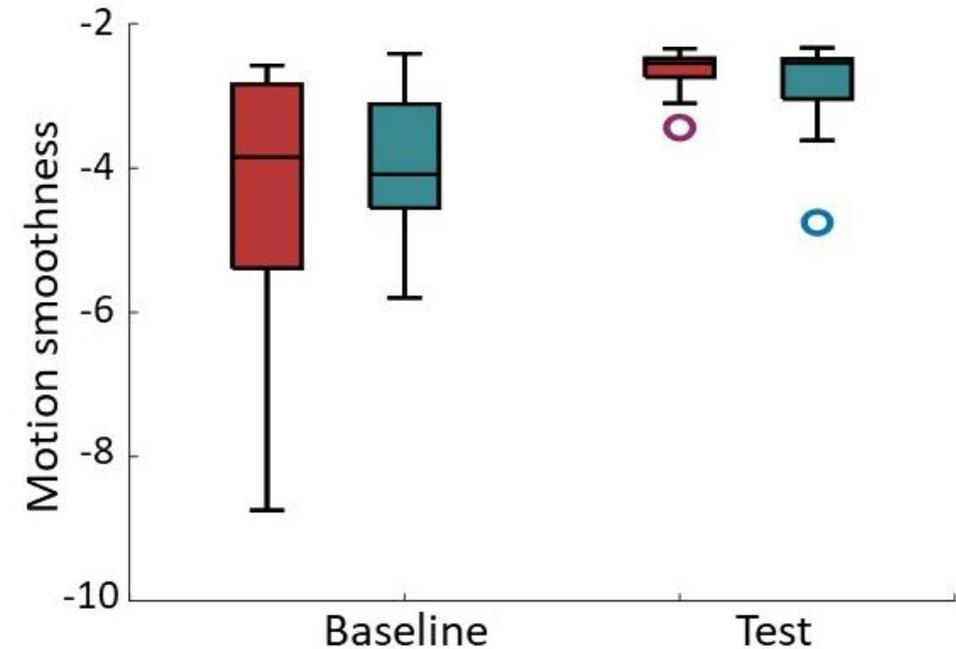
# RESULTS

# Third Hand

### Performance



### Smoothness

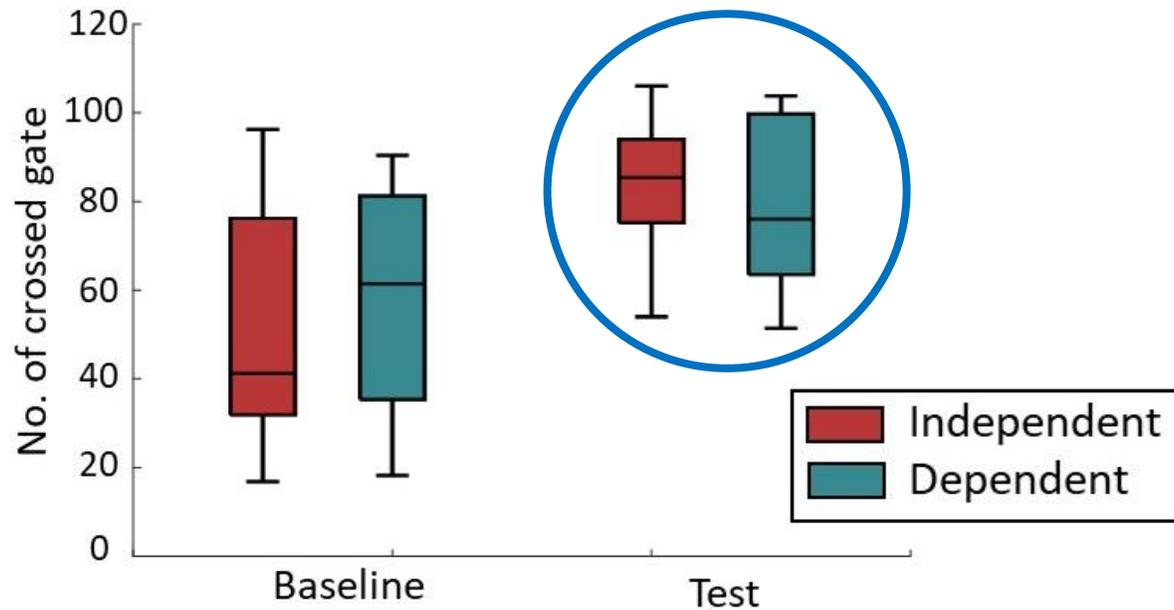


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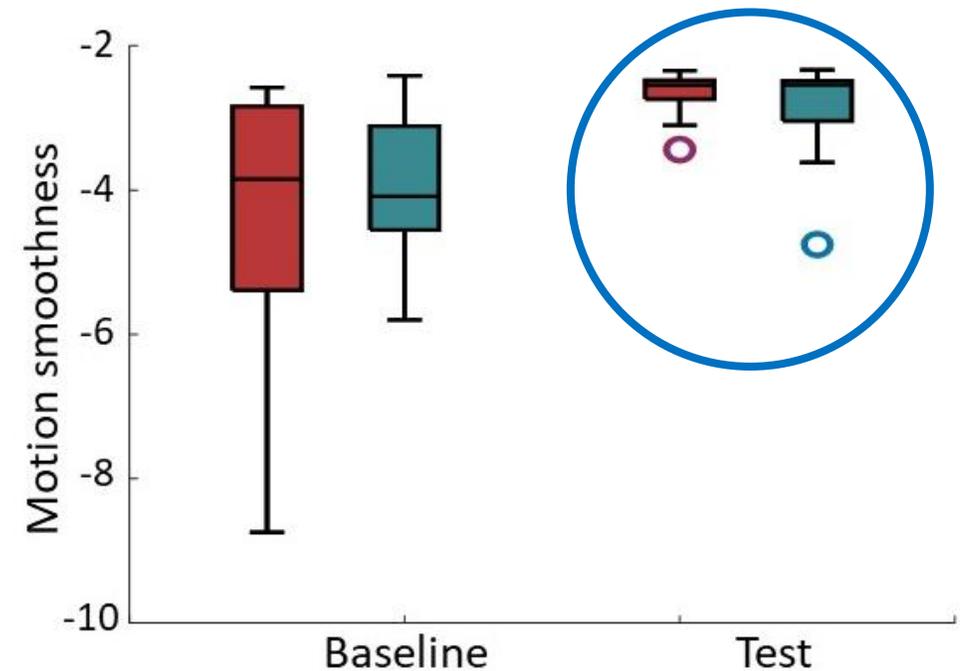
# RESULTS

# Third Hand

### Performance



### Smoothness

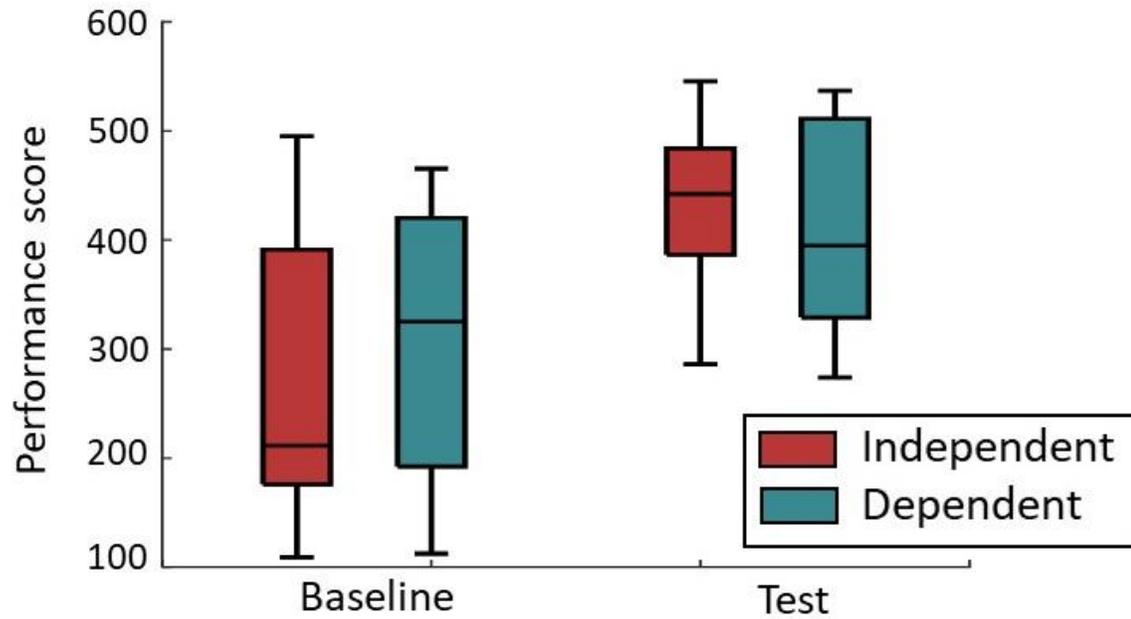


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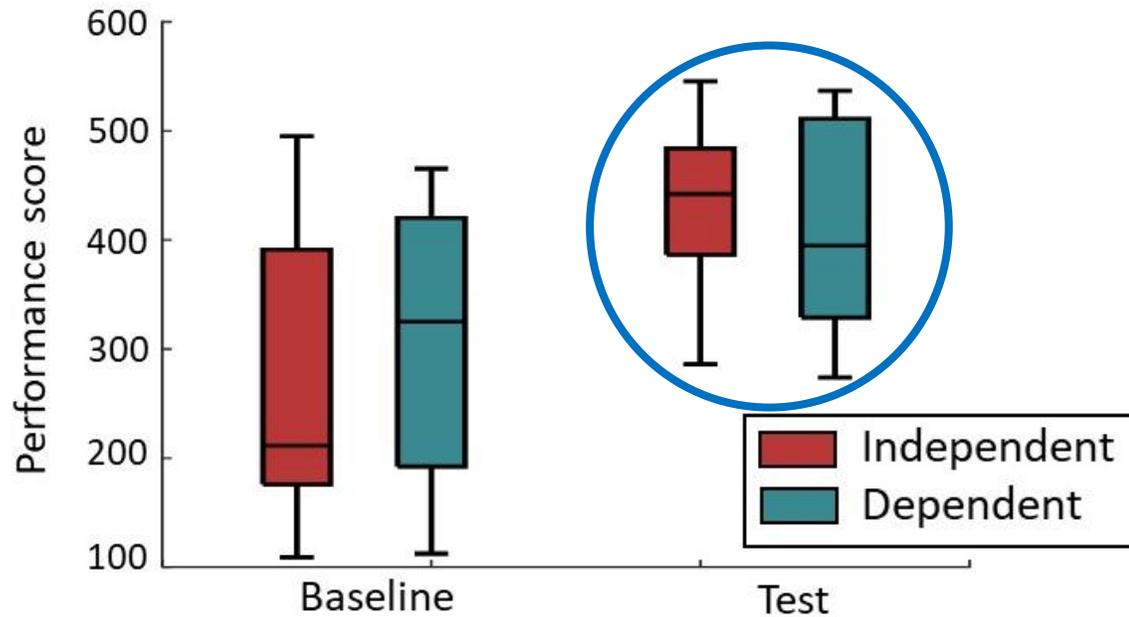
Similar tendency for the smoothness



## Performance



## Performance

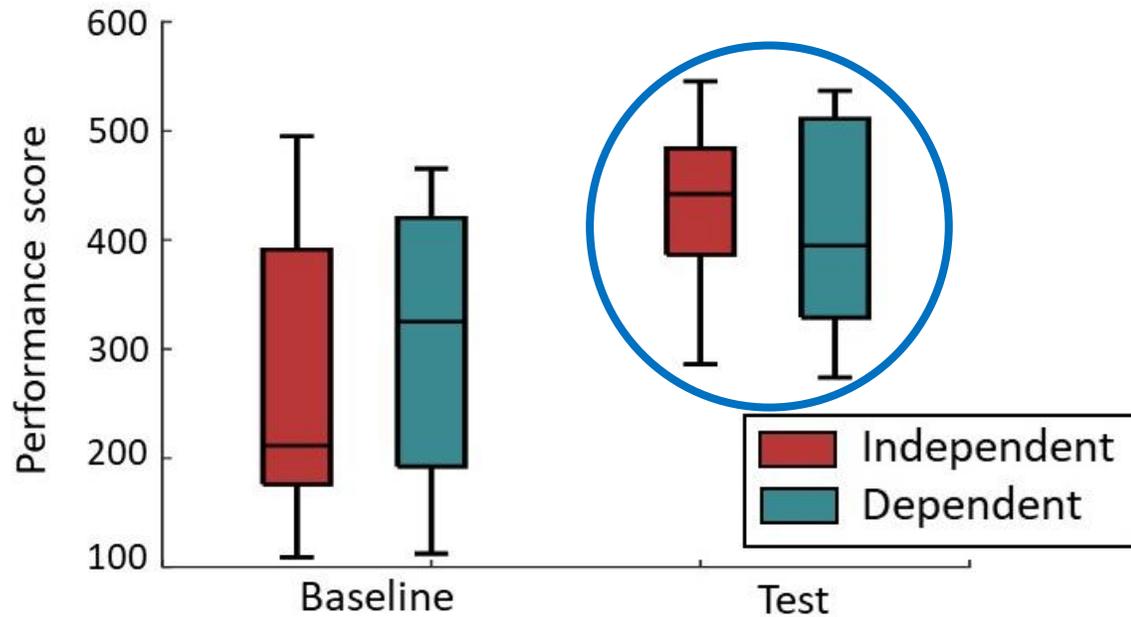


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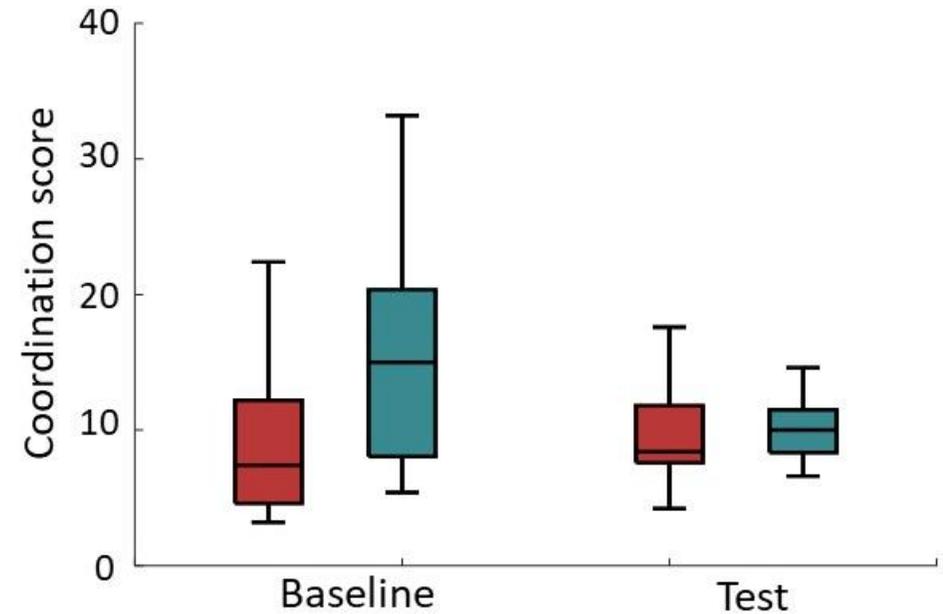
# RESULTS

# All Hands

## Performance



## Coordination

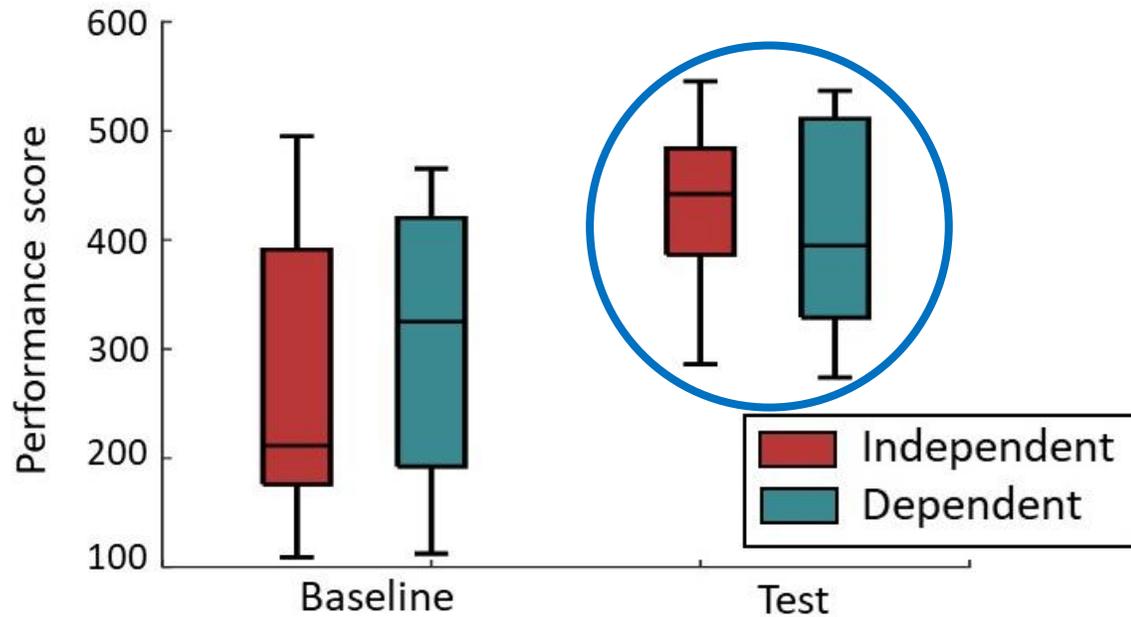


- Higher performance
- The training task has no influence

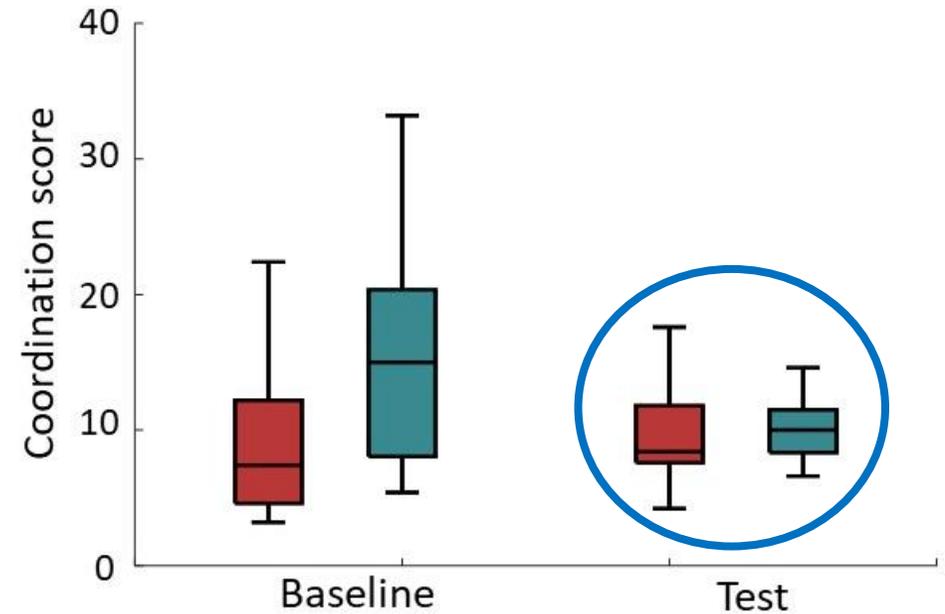
# RESULTS

# All Hands

## Performance



## Coordination



- Higher performance
- The training task has no influence

No improvement for the three hand coordination

# Discussion

# Discussion

## Summary

- We studied how different training schemes impact the learning of new trimanual skills
- The performance improvements were similar after training on both tasks
- The three-hand coordination did not improve
- Performance improvement is likely due to an improvement in the third hand's usage

# Discussion

## Summary

- We studied how different training schemes impact the learning of new trimanual skills
- The performance improvements were similar after training on both tasks
- The three-hand coordination did not improve
- Performance improvement is likely due to an improvement in the third hand's usage

## Future work

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

Thank you for your time!