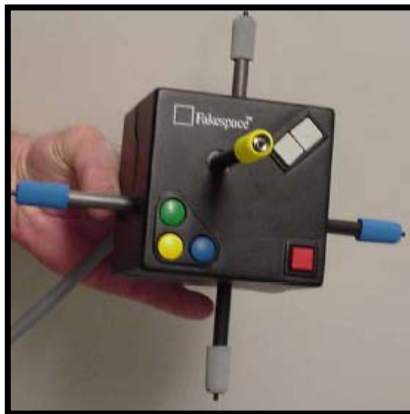




# LONG-TERM EVALUATION STUDY OF 12-DOF INPUT DEVICES FOR NAVIGATION AND MANIPULATION IN 3-D ENVIRONMENTS



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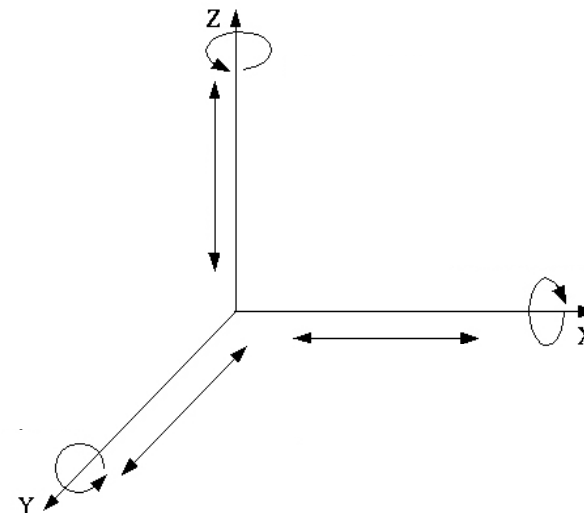
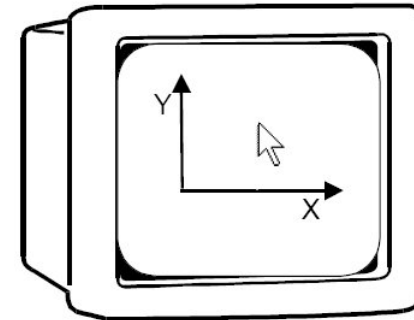
# Motivation

- Evaluation of complex technology - 12-DOF input devices for 3-D applications
- Which tasks can be controlled with these devices?
- How can these devices be evaluated?
- What are quality factors that could have an influence on usability?
- How can these be measured?



# Degrees of Freedom (DOF)

- Variables that have spatial interrelation
- Mouse has 2 DOF
- 6 DOF required to fully manipulate a single object in 3-D space



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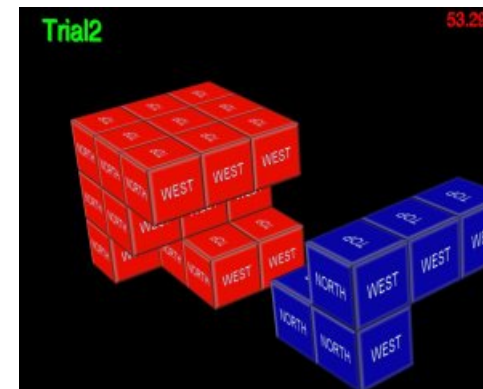
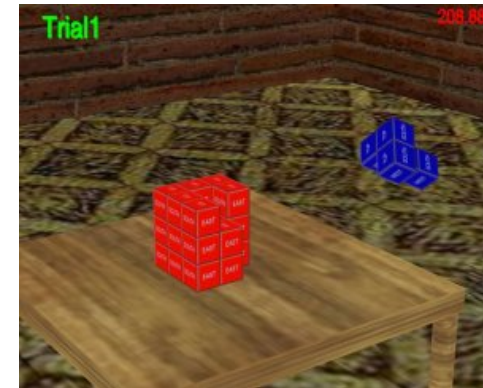
# Why 12 or more DOF?

- Applications have multiple subtasks that need to be controlled, e. g.
  - Navigation, manipulation, selection, menu control
  - Besides manipulating an object most often navigation is desired
- Navigation and manipulation are a common combination of subtasks and require 12 DOF, 6 for each subtask



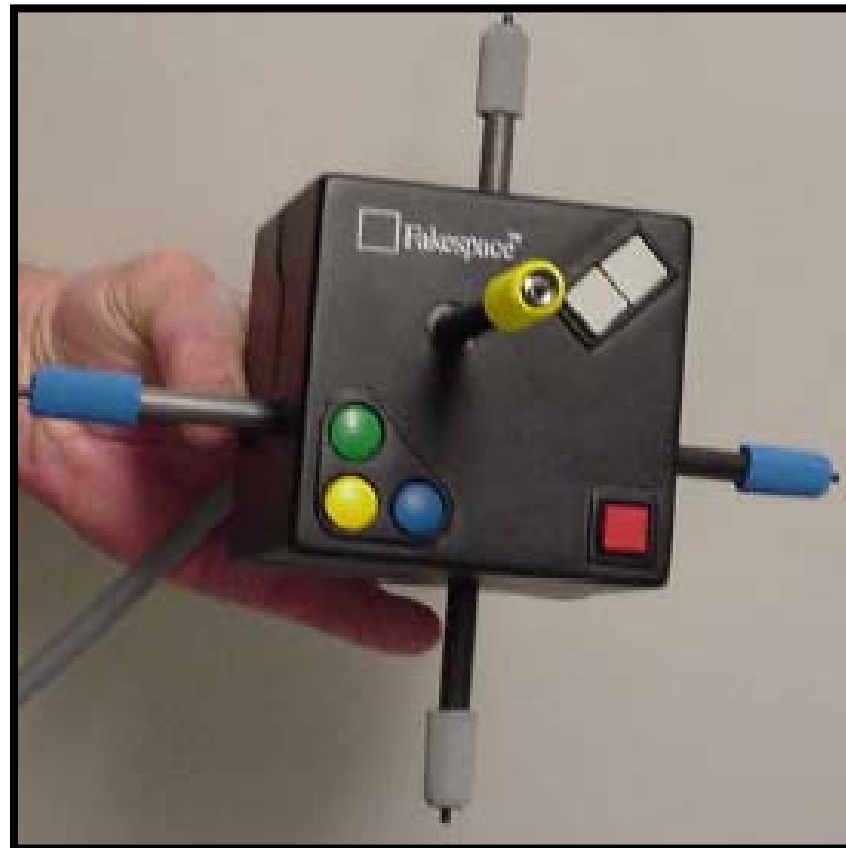
# The Extended Docking Task

- Previous evaluations of 6-DOF devices only used docking task [1, 3, 4]
- Requires navigation and manipulation for successful task completion
- Records times, coordinates and raw device signals
- Suitable task for evaluation of 12-DOF input devices
- VIDEO



# Devices – The Cubic Mouse

- Tracker – 6 DOF
- Rods – 3 x 2 DOF
- Position Control
  - Clutching
- Full tactile coordinate system
- Regrasping (rods)
- Maximum 8 DOF simultaneously



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# Devices – The YoYo

- 2 x 6 DOF
- Rate control
- Unlimited range of control
- Virtual coordinate system (tracker)
- Grip change
- Maximum 6 DOF simultaneously



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# Devices – The Square Bone

- 2 x 6 DOF
- Rate control
- Unlimited range of control
- Tactile coordinate system
- Access to all 12 DOF
- Maximum 12 DOF simultaneously



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# Hypotheses and Questions

- How does learning affect device performance?
- Device performance / comparison
  - Cubic Mouse worse than others due to manipulation DOF separation
- Will changing output and display conditions affect performance?



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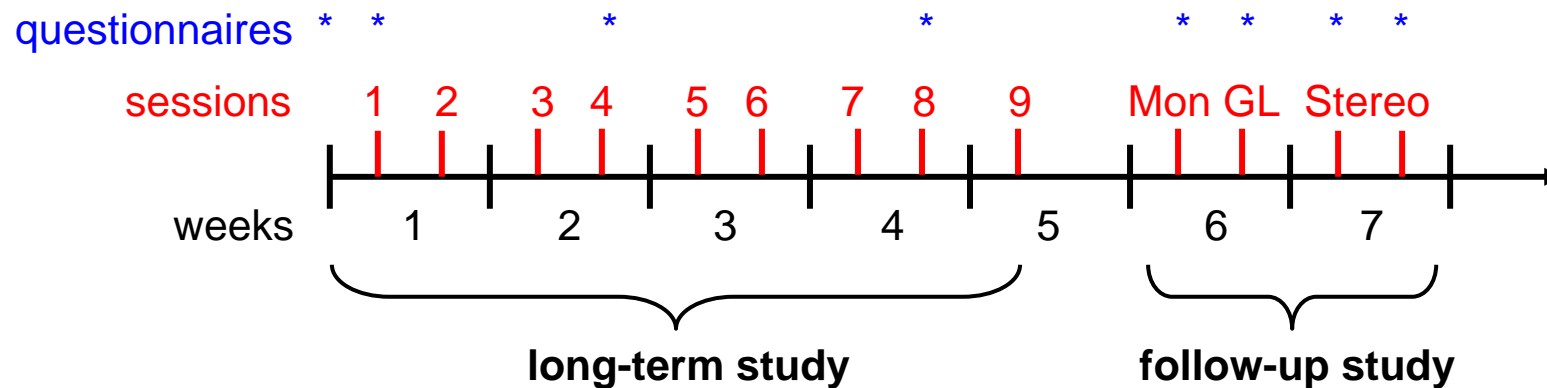
# Methods

- Task
  - Extended docking task with monitor in mono for long-term study
  - Follow-up study used large projection screen and stereo
- 8 participants
  - two female, six male
  - age from 20 to 29 (23.6 average)
  - all right-handed
  - 50% less experienced, 50% more experienced



# Methods

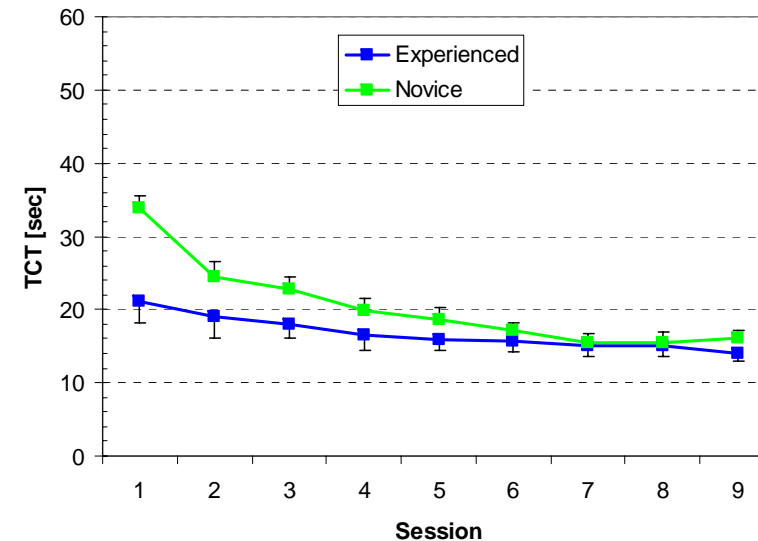
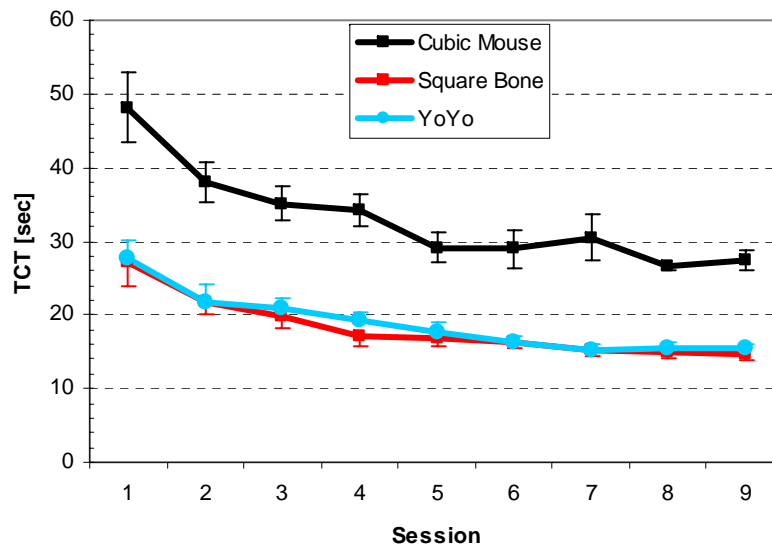
- Study time line



- 2 to 3 days between each session
  - average session duration: 45 min
- 2160 + 960 trials, 847890 device signal data lines



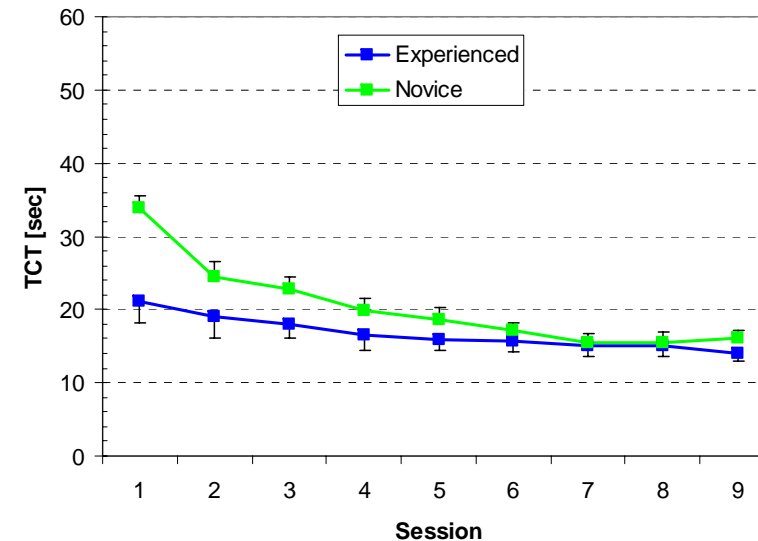
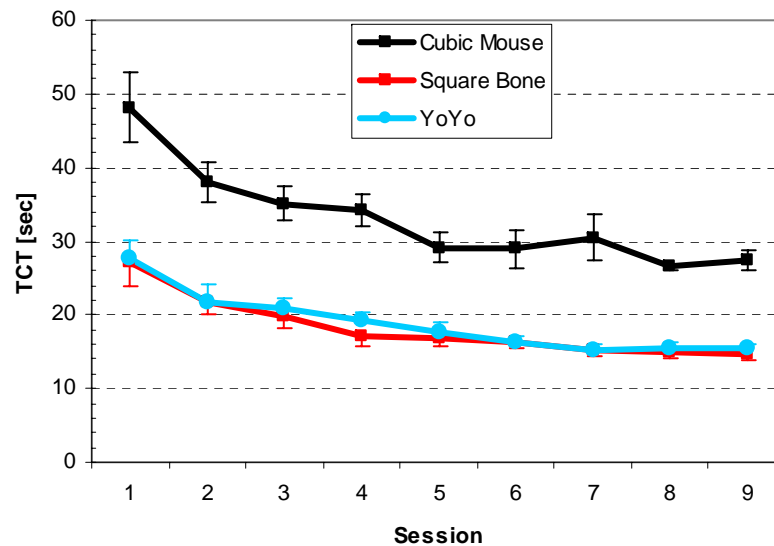
# Task Completion Times (TCTs)



- Cubic Mouse significantly worse than other devices
- After session 5 no more statistical difference between novice and experienced users



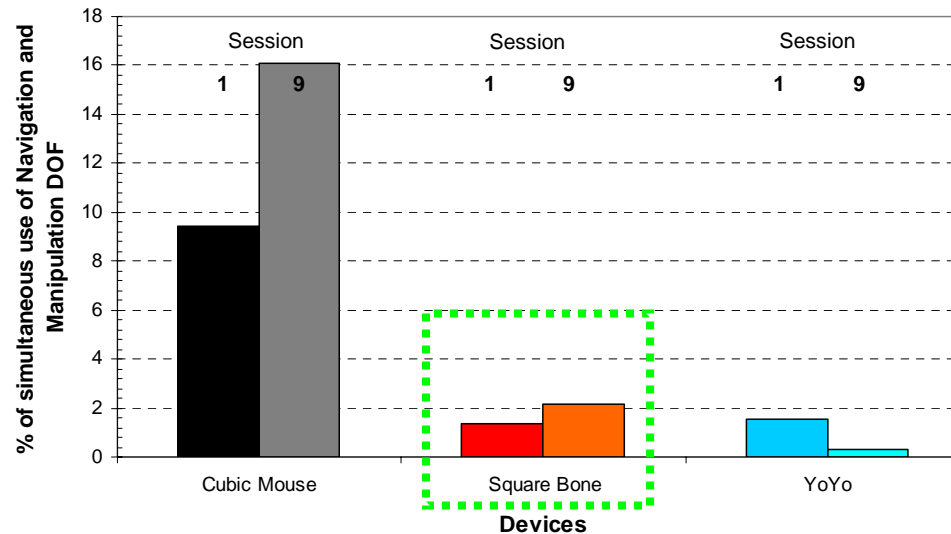
# Learning Behavior, Variability



- Equal learning behavior for the devices
- Novice users have steeper learning function than expert users (function fitting)
- Variability decreased approximately equally for YoYo and Square Bone, for the Cubic Mouse much more but on higher level



# Simultaneous Control of Navigation and Manipulation



- Simultaneous control of navigation and manipulation DOF with the Square Bone significantly correlated ( $r=0.13$ ) with lower TCTs

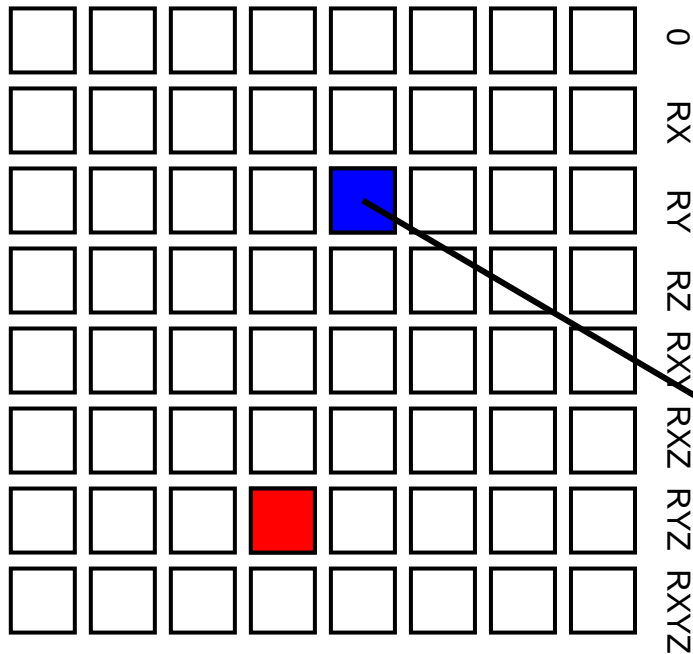


# Visualization Concept for Simultaneous Control

0.1 0.15 0.4 0.05 0.45 0.5 0.1 0.2 0.1 0.1 0 0  
 0.4 0.4 0.1 0.05 0.5 0.1 0.1 0 0 0.4 0.5

Navigation

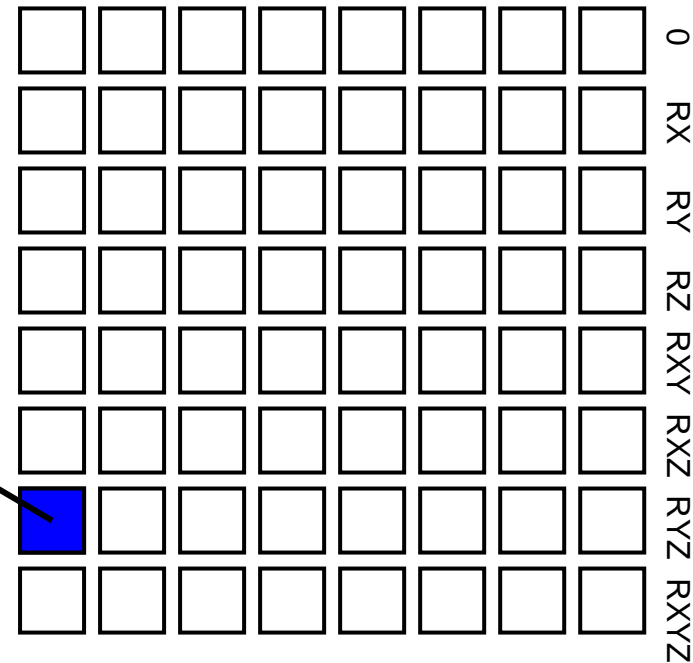
0 TX TY TZ TXY TXZ TYZ TXYZ



001011 000000  
 110010 000011

Manipulation

0 TX TY TZ TXY TXZ TYZ TXYZ

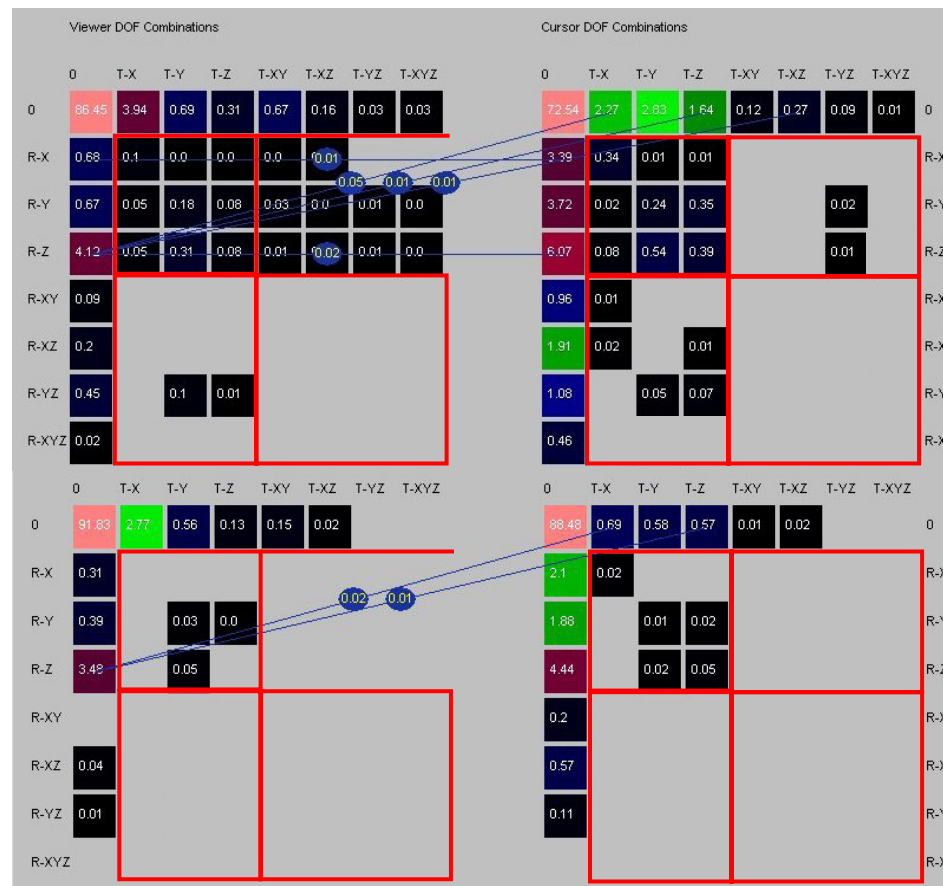


# Intended Simultaneous Control with the Square Bone

Threshold

- 0.5

- 0.75



complete data



# Unintended Simultaneous Control with the YoYo

Threshold

- 0.5

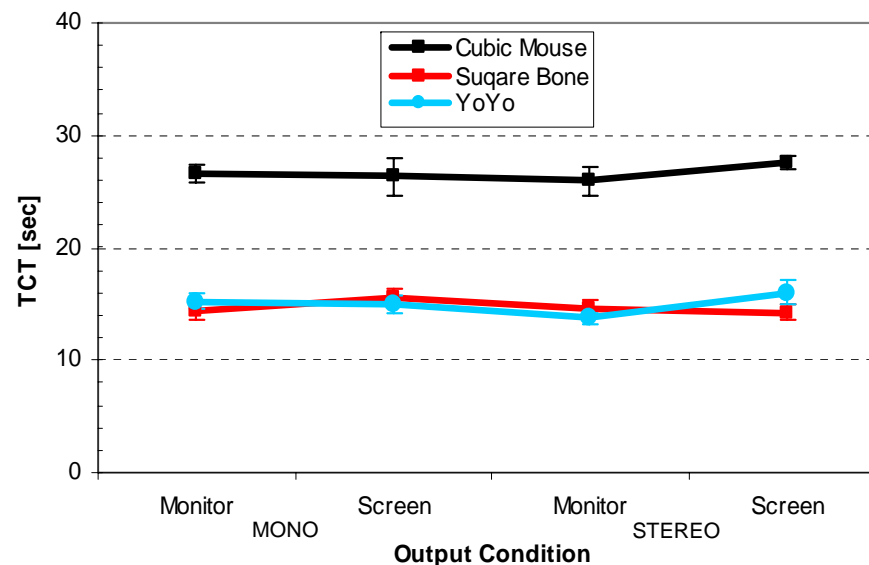
- 0.75



complete data



# TCTs with changing Output and Display Conditions



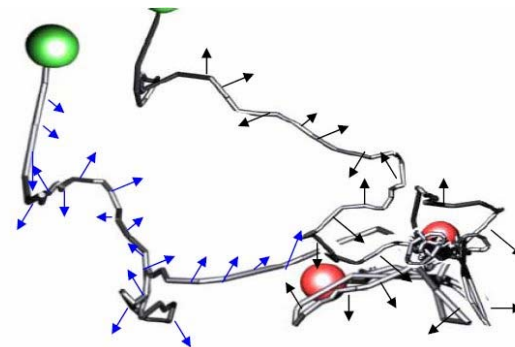
- No significant differences for changing output devices and display modes
- Subjective data confirms all measured results



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# Future Work - Evaluations

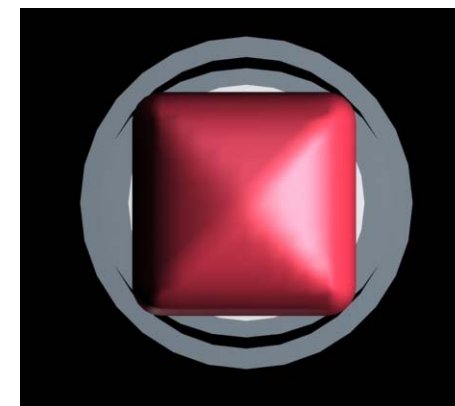
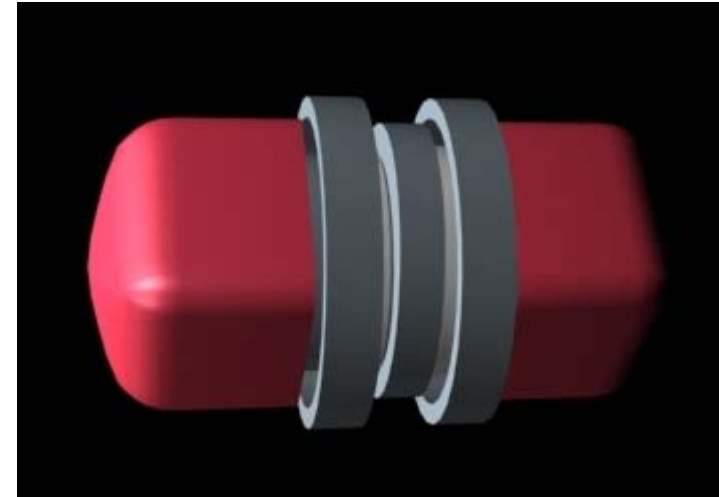
- Future studies should regard isolated features
  - Coordinate system, degree of DOF separation
- Further subtask combinations should be added and tested
  - Selection, menu control commands
- Trajectory based analysis of navigation and manipulation
  - Question of optimal navigation remains open



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# Future Work - Devices

- Wireless standard IEEE-802.15.4 “Zigbee” for peripheral computing devices should be adopted and tested
- Rotational position control and translational rate control
- Square Bone II should displace tactile coordinate system to caps and integrate a tracker



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# References

- [1] Masliah, M., “Measuring the allocation of control in 6 Degree of Freedom Human-Computer Interaction Tasks”, PhD-Thesis, University of Toronto (2001).
- [2] Speed, A., “Long-term Evaluation Study of 12-DOF Input Devices for Navigation and Manipulation in 3-D Environments”, unpublished Bachelor Thesis, Bauhaus University Weimar (2005)
- [3] Zhai, S., “Human Performance in Six Degree of Freedom Input Control”, PhD-Thesis, University of Toronto (1995).
- [4] Zhai, S. and Milgram, P., “Quantifying Coordination in Multiple DOF Movements and Its Application to Evaluating 6 DOF Input Devices”, Proceedings of CHI 1998 (1998), 320-327.

