COE CST Eleventh Annual Technical Meeting

Human Input Systems for Commercial Space Transportation

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Troy R Weekes, Researcher

Kazuhiko Momose (PhD student)
Andrew Biron (PhD Student)

Agenda

- Team Members
- Task Description
- Schedule
- Goals
- Results
- Conclusions and Future Work

Team Members

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Troy
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Student

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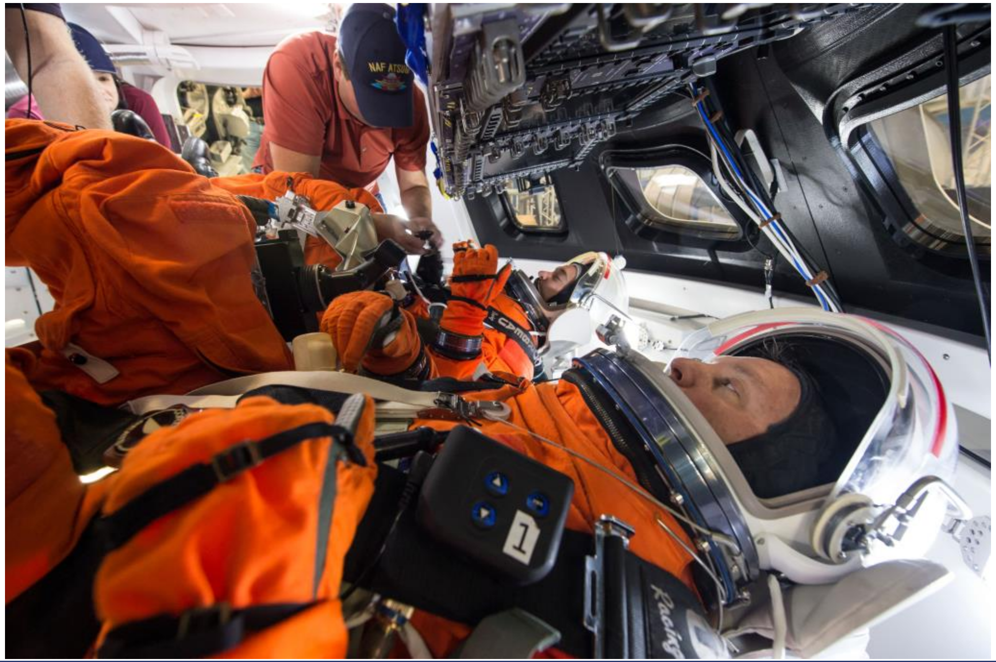
Student

Task Description

- This project will develop guides for the CST industry in the area of definition and engineering of CST control input devices and systems usable in variable gravity with or without spacesuit.

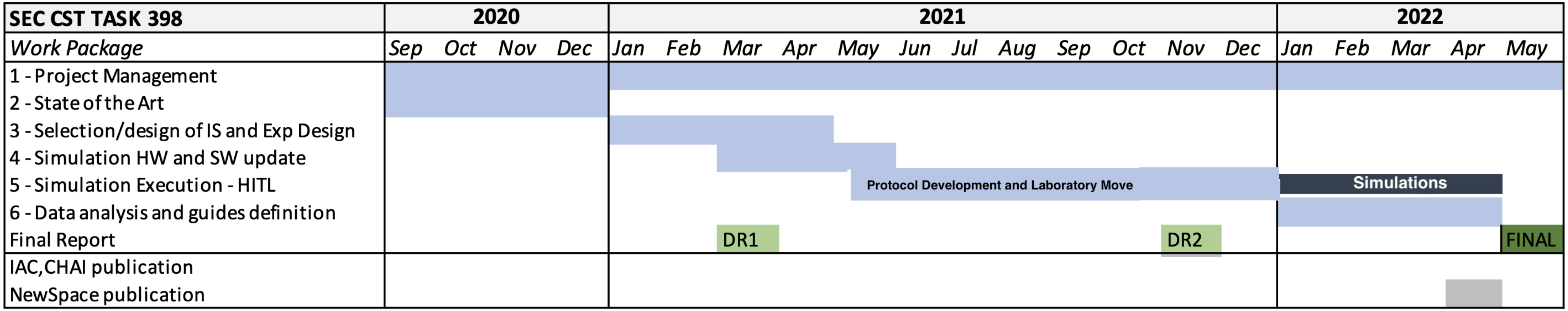


Control in Variable Gravity

- Control of vehicles require
  - good visual acuity,
  - eye-hand coordination,
  - spatial and geographic orientation perception, and
  - cognitive function.
- Space flight research has demonstrated the effects of variable gravity on each of these requirements

Bloomberg JJ, Reschke MF, Clément GR, Mulavara AP, Taylor LC. NASA evidence report: Risk of impaired control of spacecraft/associated systems and decreased mobility due to vestibular/sensorimotor alterations associated with space flight. 2016. [September 12, 2016]. https://humanresearchroadmap.nasa.gov/Evidence/reports/SM.pdf. [Reference list]

Schedule


SEC CST TASK 398
2020
2021
2022
Work Package
Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May
1 - Project Management
2 - State of the Art
3 - Selection/design of IS and Exp Design
4 - Simulation HW and SW update
5 - Simulation Execution - HITL
6 - Data analysis and guides definition
Final Report
IAC,CHAI publication
NewSpace publication
Protocol Development and Laboratory Move
Simulations
DR1
DR2
FINAL

Goals

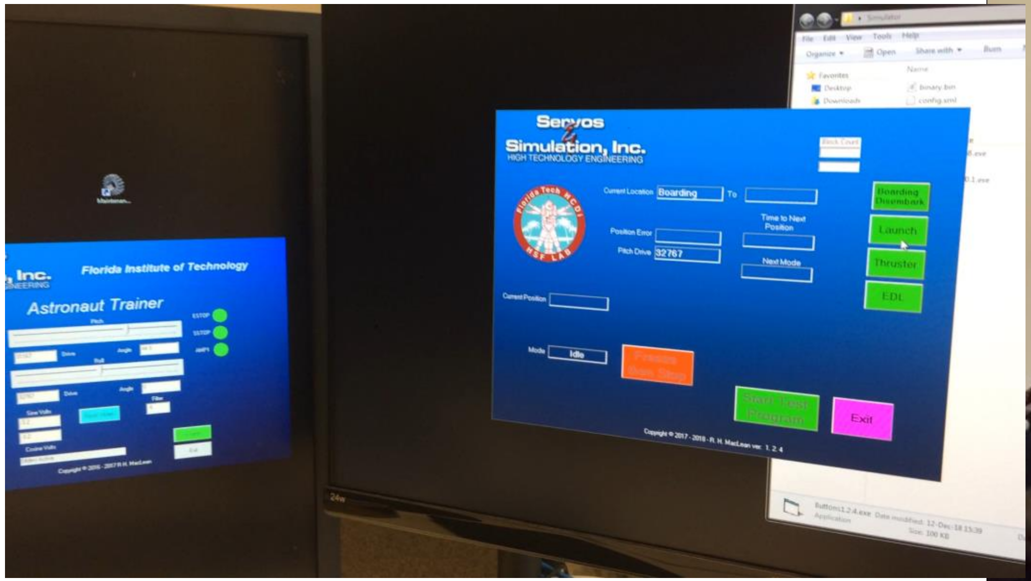
1. **Identify the best human input physio-cognitive control logic and mechanisms for human operators in variable gravity environment**
2. Identify satisfactory multimodal feedback for confirmation of actions in hyperbaric, variable gravity environment.
3. A homing function for input devices can be misinterpreted when using spacesuit and/or operating the vehicle in variable gravity environment. Determine whether an input device should have a homing function and, if so, how it should be communicated to the user.
4. Identify the personal physical and cognitive ergonomic features of vehicle occupants that should be driving the cockpit cognitive and physical ergonomics adaptation.
5. Determine fundamental rules of how to secure optimal performance of the mission and safety of astronauts in interactions with adaptive automation

Simulating Microgravity

- Microgravity has a number of effects on astronauts and space tourists
- 23% of shuttle astronauts had near-vision changes in flight and 11% post-flight
- 48% of long-term astronauts had vision issues
  - Edema
  - Flattening
  - “wool” spots
  - Kinked optic nerves
- Intraocular pressure differences were noticed as far back as Gemini V and VII

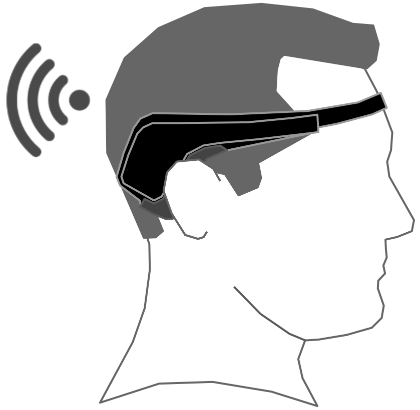
E. Seedhouse (2015), *Microgravity and Vision Impairments in Astronauts,* SpringerBriefs in Space Development , Springer International Publishing Switzerland

FIT Microgravity Simulator



Cognitive Ergonomics

1 BIO-SIGNALS

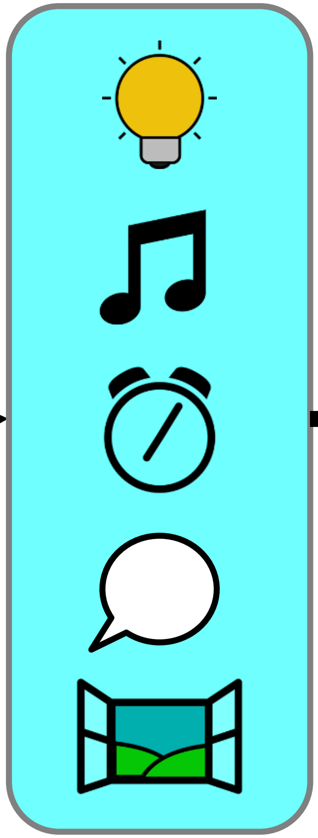


2 OPERATOR STATES

Cognitive State		Affective State			
Disengaged	Engaged	Bored	Neutral	Happy	Anxious

3 CONTEXT

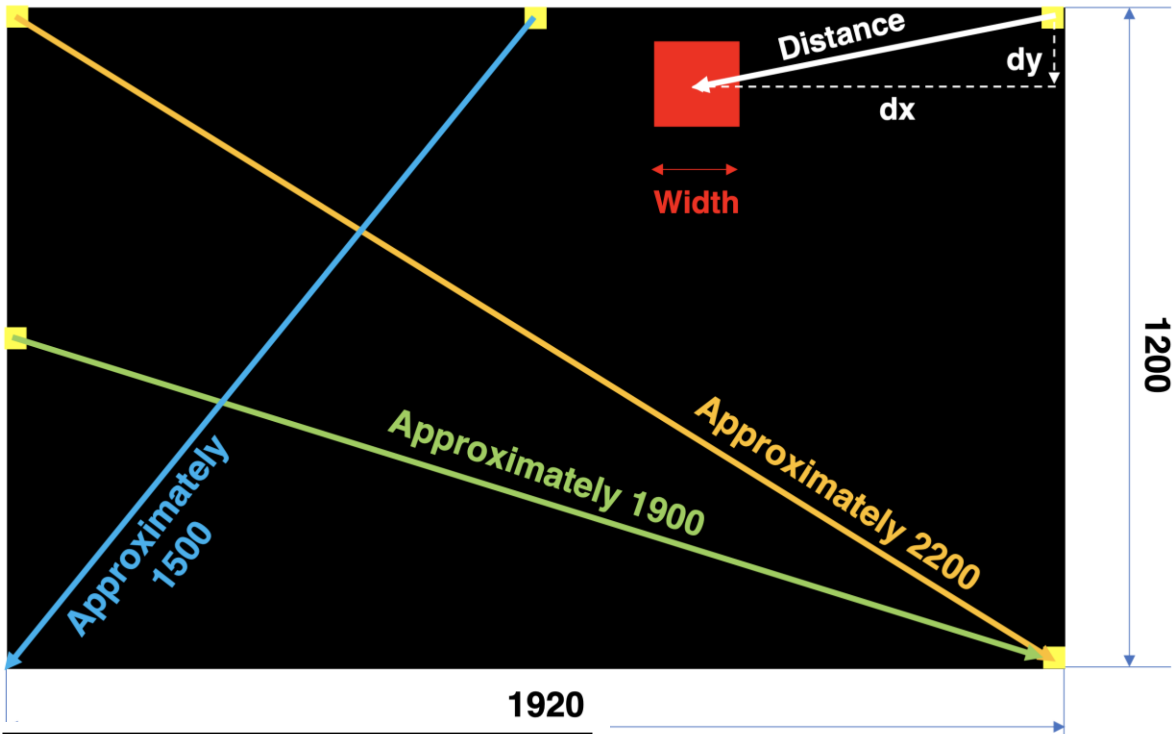
4 NUDGES

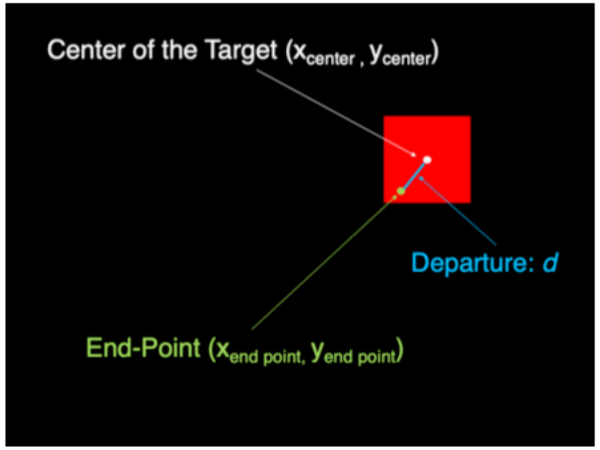


5 FLOW EXPERIENCE

Eskridge, Thomas C, and Weekes, Troy R (2020) **Opportunities for Case-based Reasoning in Personal Flow and Productivity Management,** *In Proceedings of the 28th International Conference on Case-based Reasoning (ICCBR-2020)* 2020

Fitt's Task

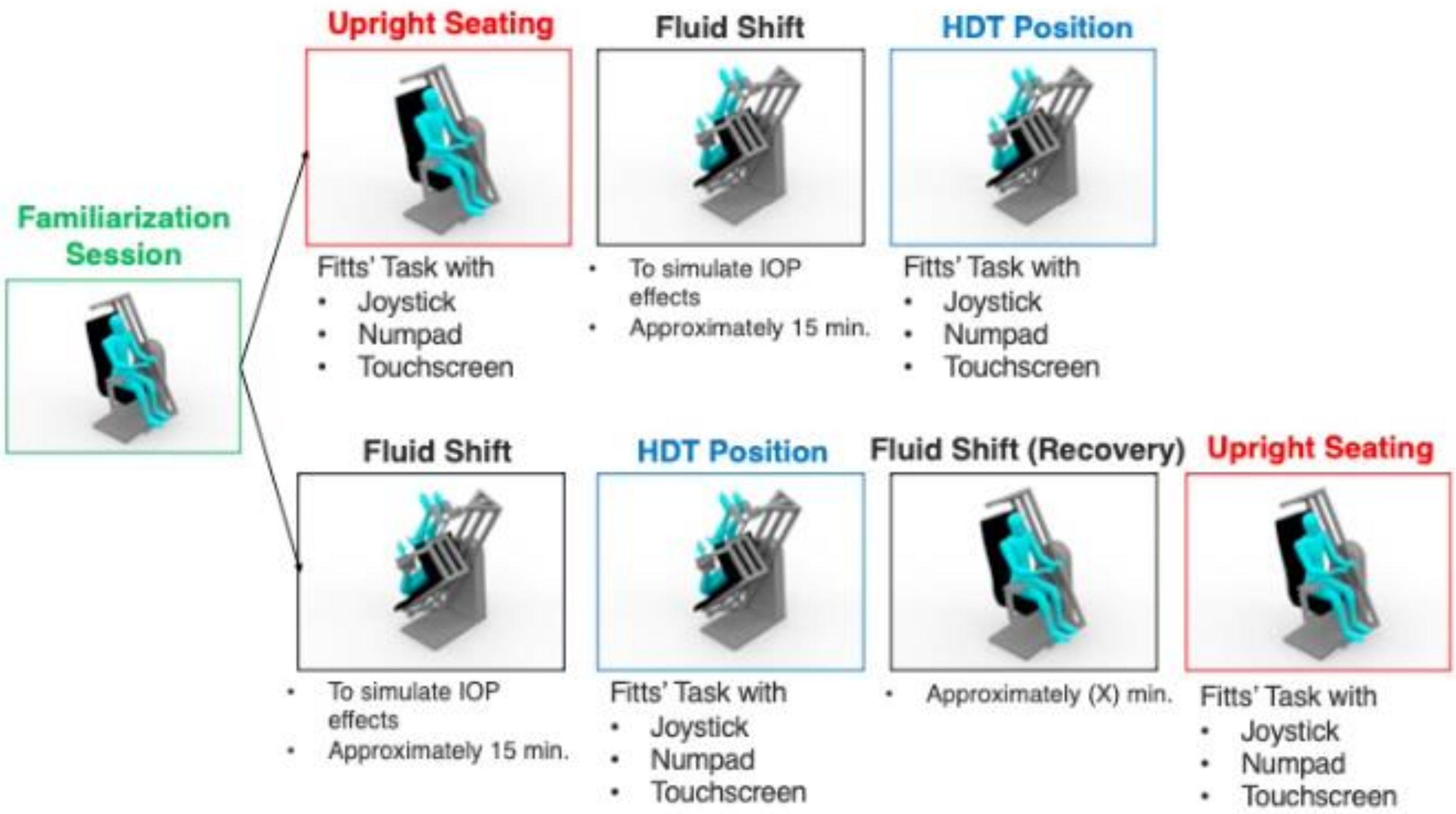




$$ID = log_2(\frac{2D}{W})$$

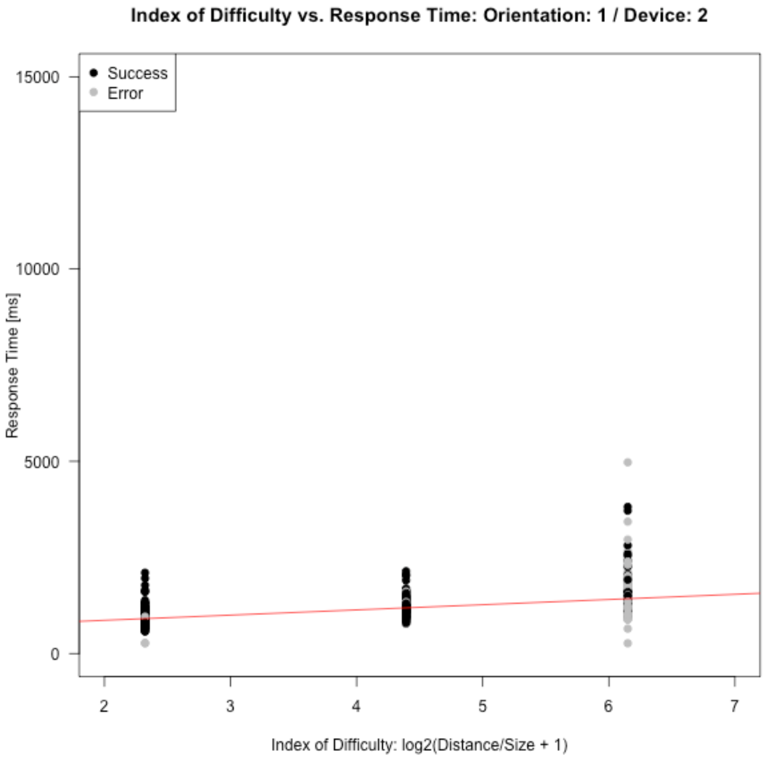
$$MT = a + bID$$

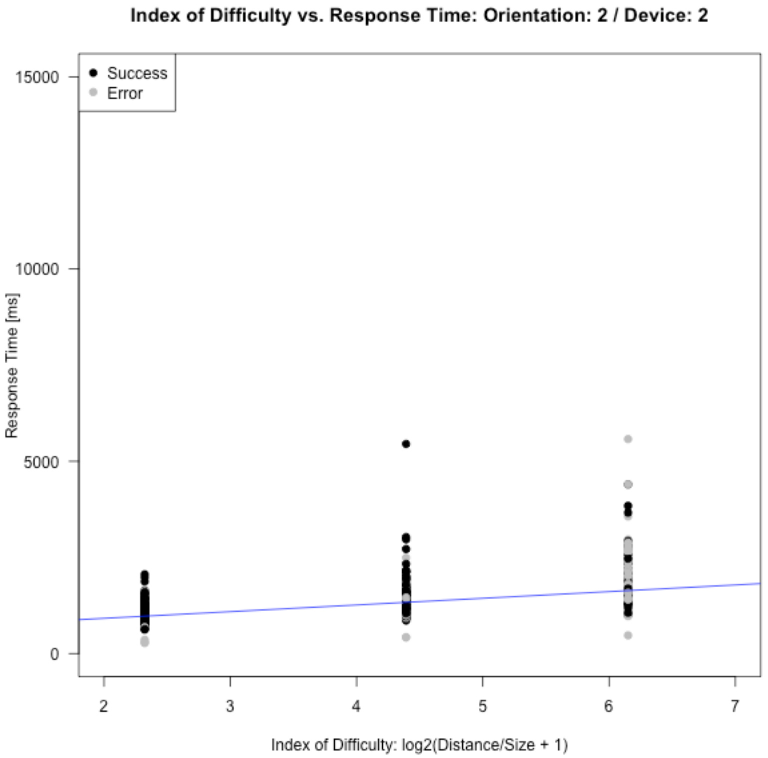
Method



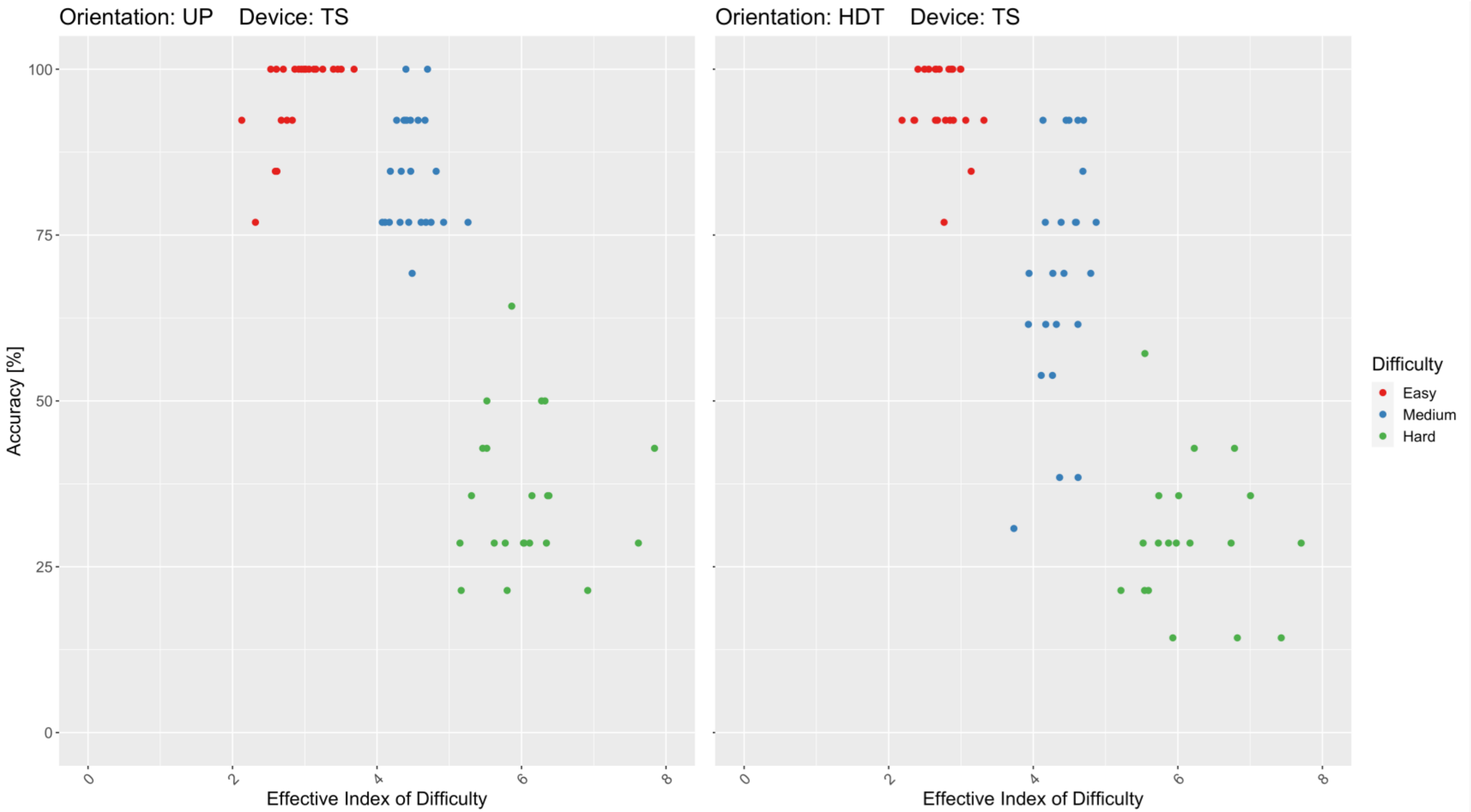
Familiarization Session
Upright Seating
Fitts' Task with
• Joystick
• Numpad
• Touchscreen
Fluid Shift
• To simulate IOP effects
• Approximately 15 min.
HDT Position
Fitts' Task with
• Joystick
• Numpad
• Touchscreen
Fluid Shift
• To simulate IOP effects
• Approximately 15 min.
HDT Position
Fitts' Task with
• Joystick
• Numpad
• Touchscreen
Fluid Shift (Recovery)
• Approximately (X) min.
Upright Seating
Fitts' Task with
• Joystick
• Numpad
• Touchscreen

TouchScreen

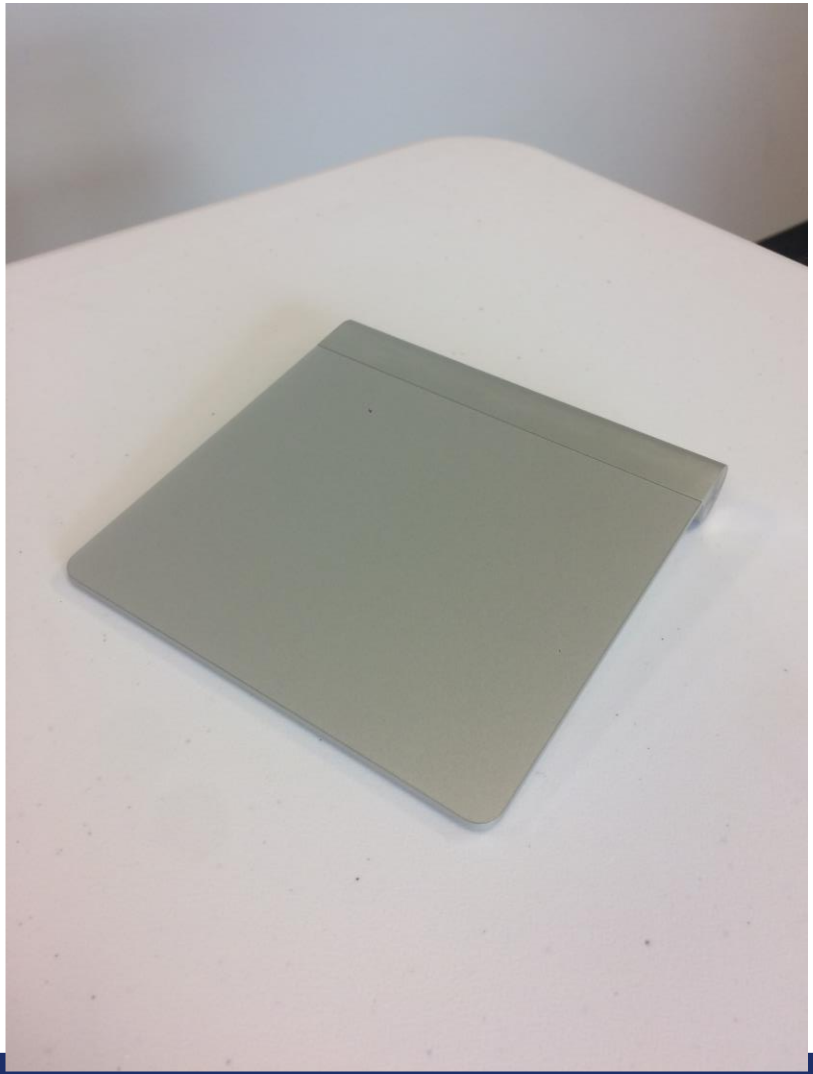


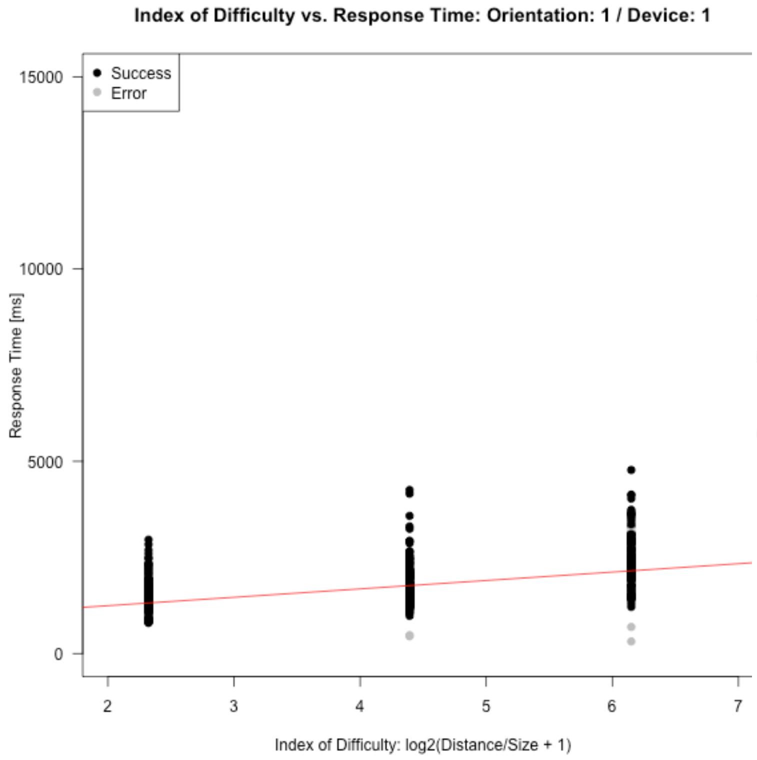


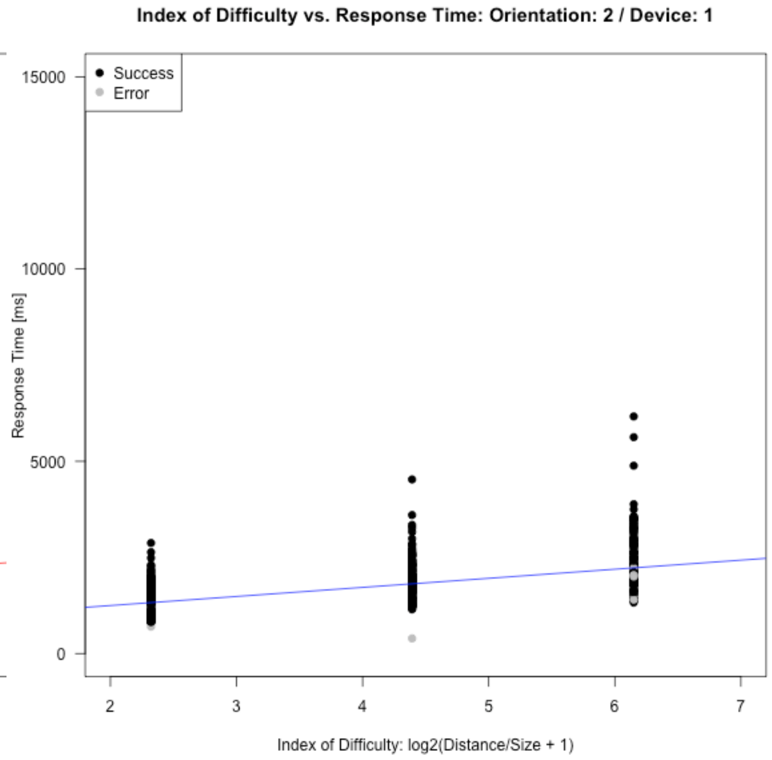
TouchScreen



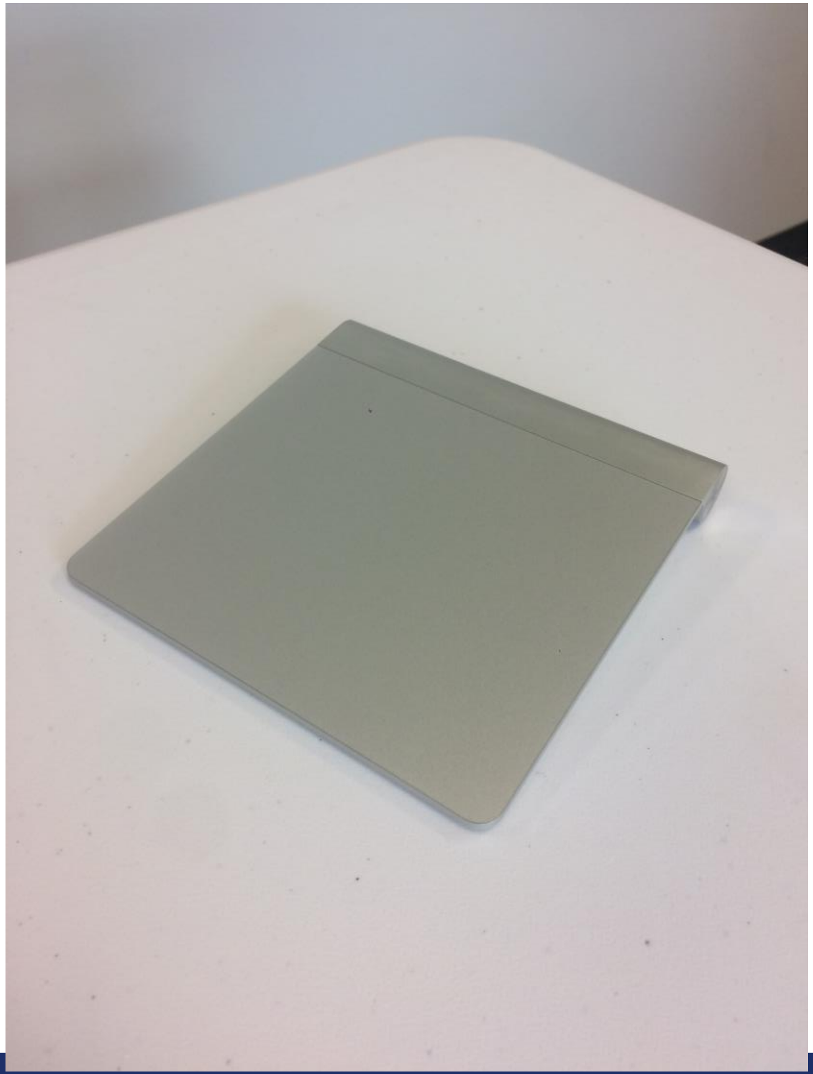
Trackpad

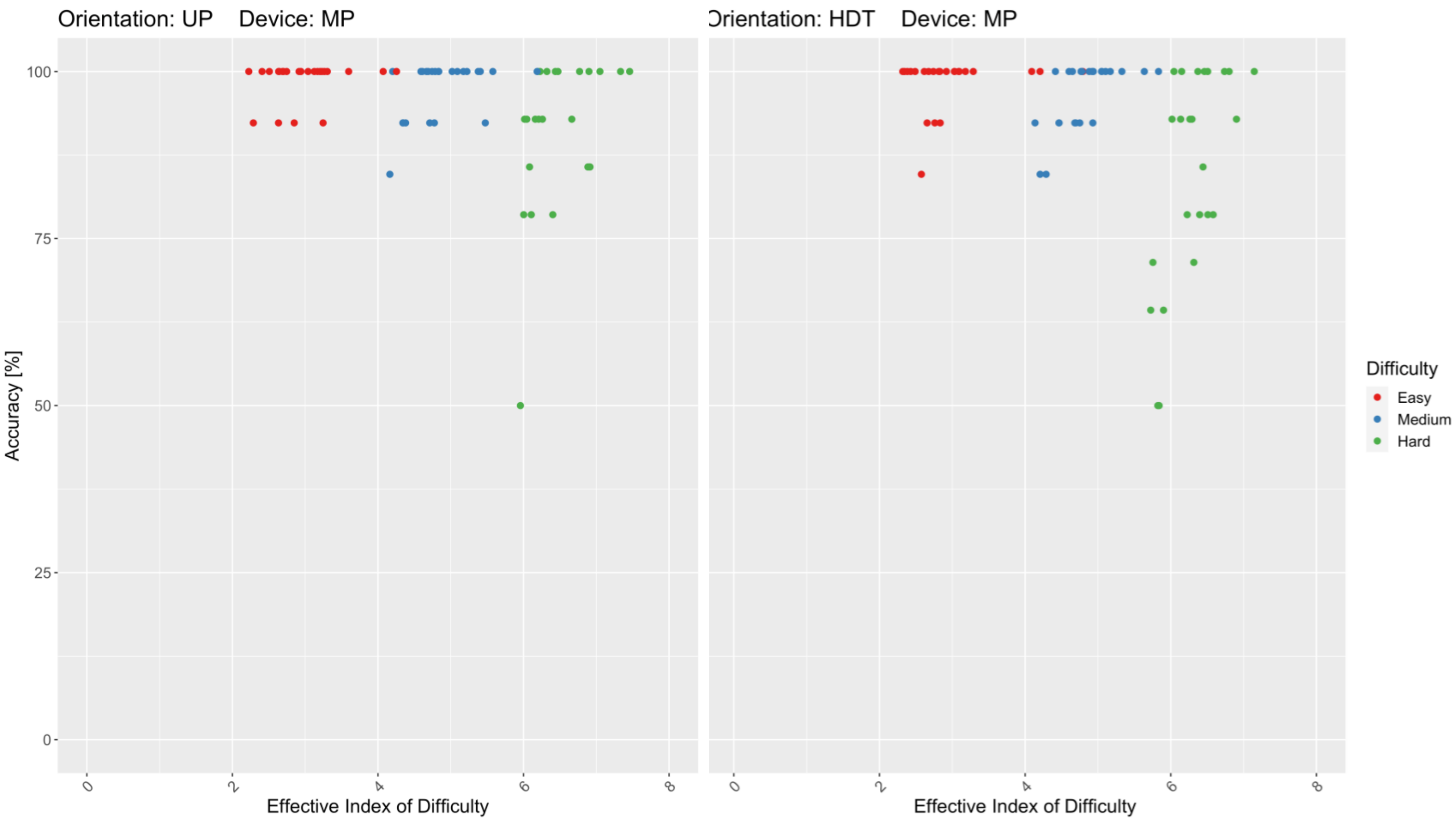



Index of Difficulty vs. Response Time: Orientation: 1 / Device: 1
Success
Error
15000
10000
5000
0
Response Time [ms]
2
3
4
5
6
7
Index of Difficulty: log2(Distance/Size + 1)

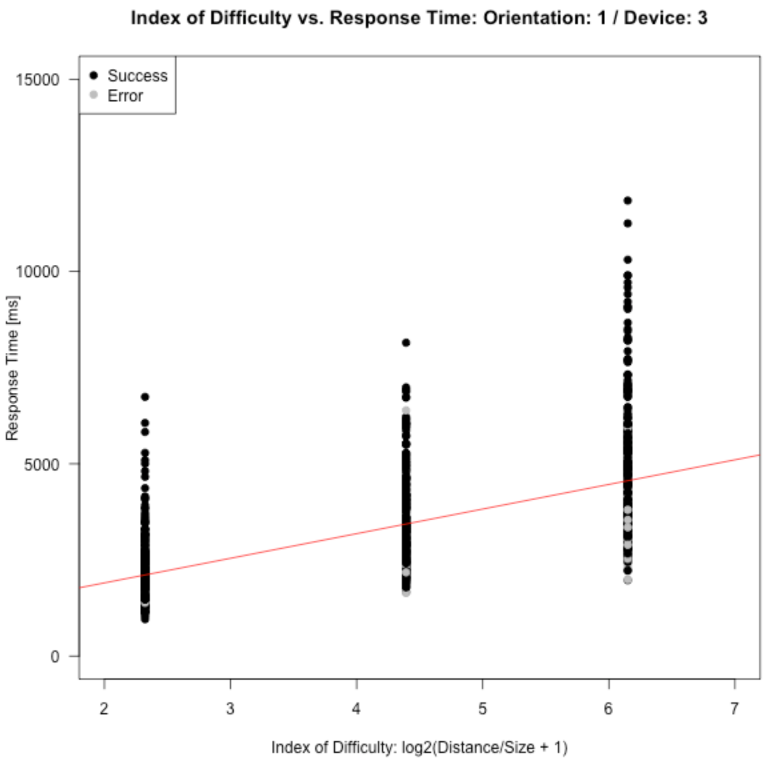

Index of Difficulty vs. Response Time: Orientation: 2 / Device: 1
Success
Error
15000
10000
5000
0
Response Time [ms]
2
3
4
5
6
7
Index of Difficulty: log2(Distance/Size + 1)

Trackpad

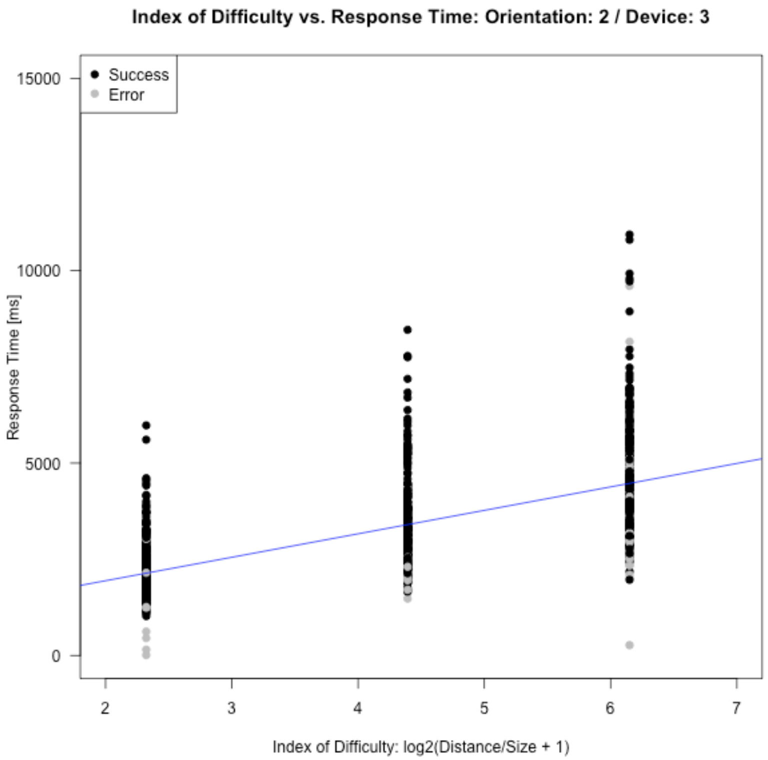



Orientation: UP Device: MP
Orientation: HDT Device: MP
Accuracy [%]
100
75
50
25
0
0
2
4
6
8
Effective Index of Difficulty
Difficulty
Easy
Medium
Hard

Joystick

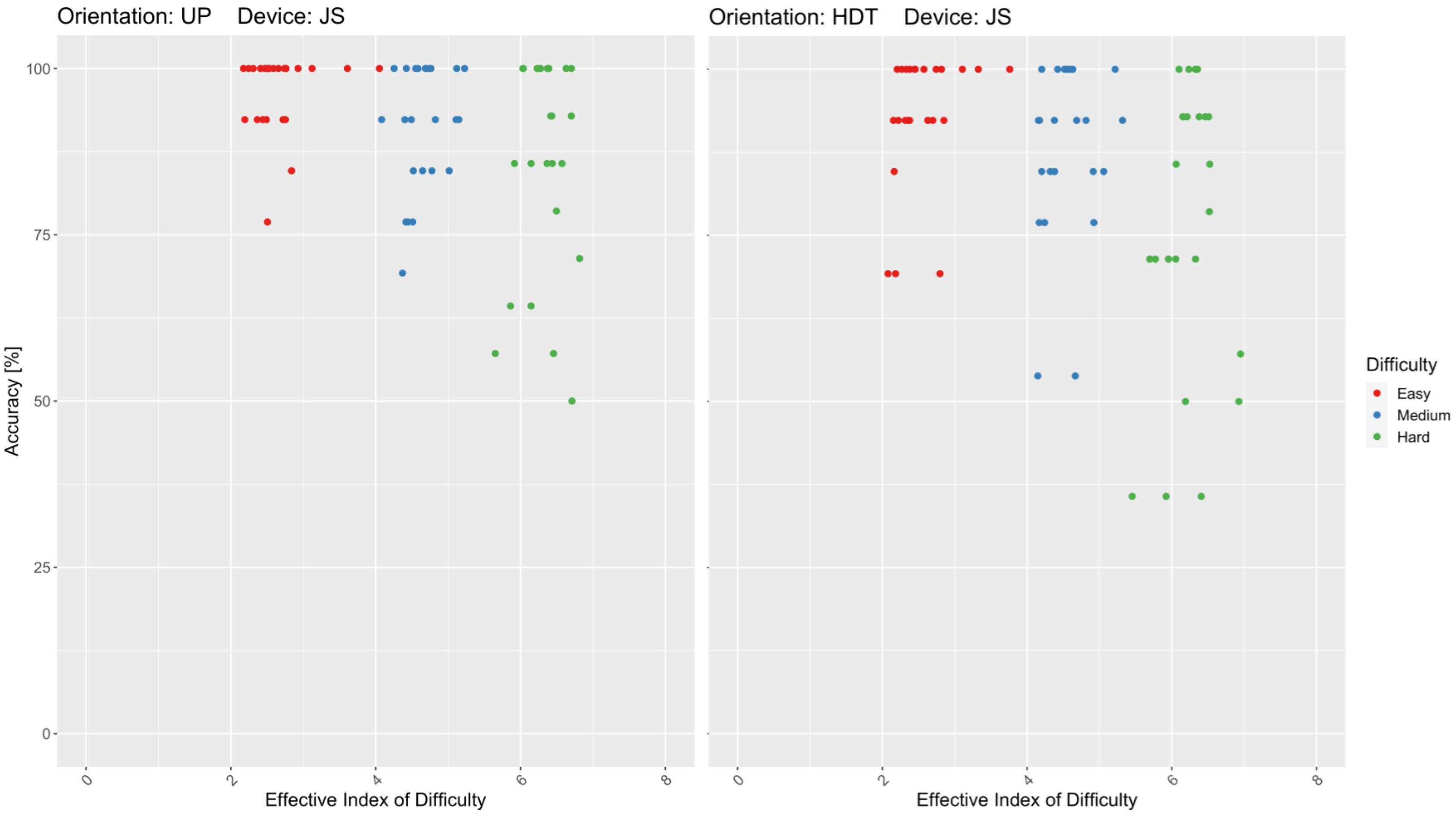


Index of Difficulty vs. Response Time: Orientation: 1 / Device: 3
Success
Error
15000
10000
5000
0
Response Time [ms]
2
3
4
5
6
7
Index of Difficulty: log2(Distance/Size + 1)



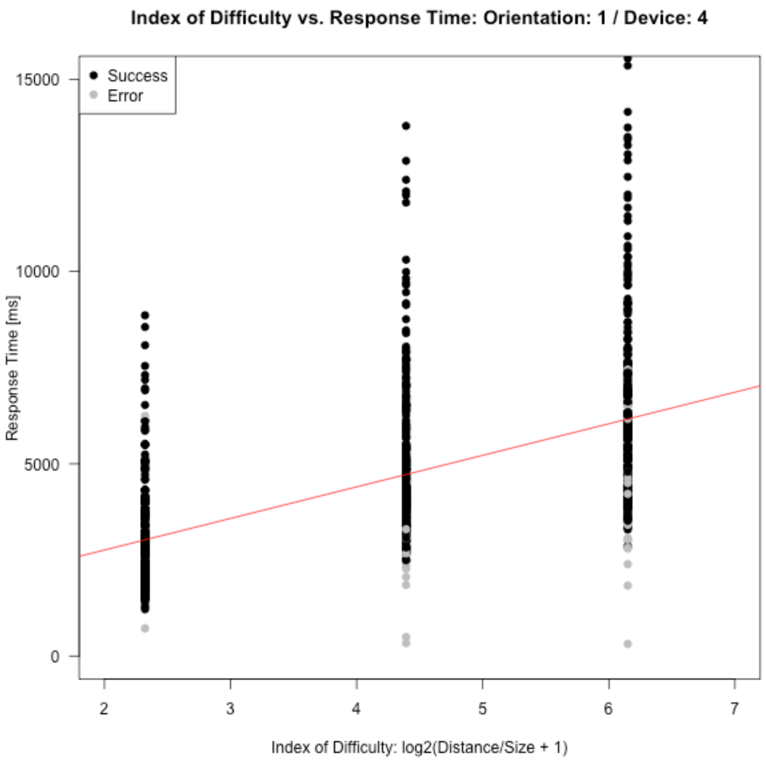
Index of Difficulty vs. Response Time: Orientation: 2 / Device: 3
Success
Error
15000
10000
5000
0
Response Time [ms]
2
3
4
5
6
7
Index of Difficulty: log2(Distance/Size + 1)

Joystick

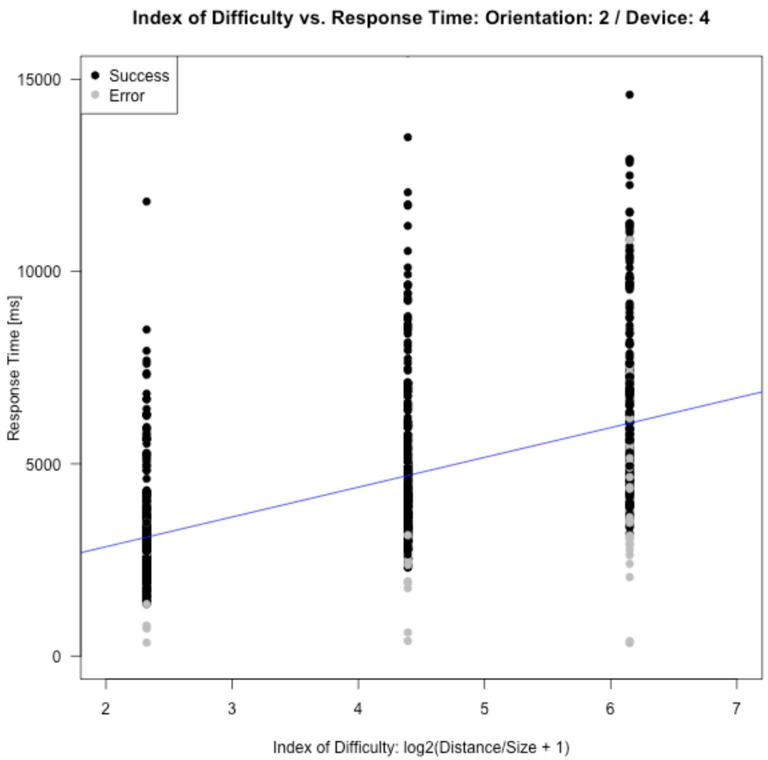

Orientation: UP Device: JS
Orientation: HDT Device: JS
Accuracy [%]
100
75
50
25
0
0
2
4
6
8
Effective Index of Difficulty
Effective Index of Difficulty
Difficulty
Easy
Medium
Hard

Keypad

NUM LOCK
BACK SPACE
7
HOME
8
9
PG UP
4
5
6
1
END
2
3
PG DN
INS
DEL
ENTER



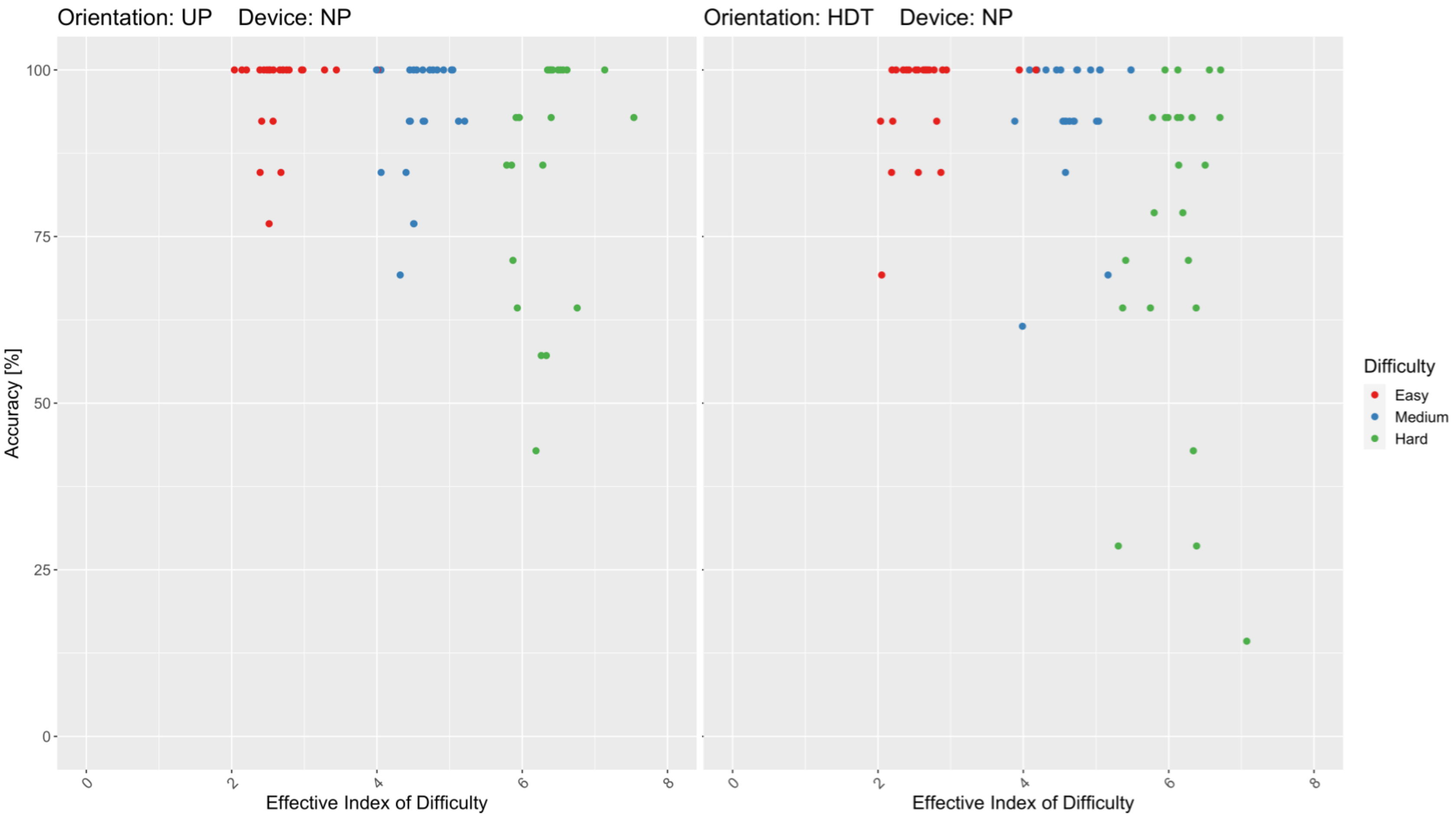
Index of Difficulty vs. Response Time: Orientation: 1 / Device: 4
Success
Error
Response Time [ms]
Index of Difficulty: log2(Distance/Size + 1)



Index of Difficulty vs. Response Time: Orientation: 2 / Device: 4
Success
Error
Response Time [ms]
Index of Difficulty: log2(Distance/Size + 1)

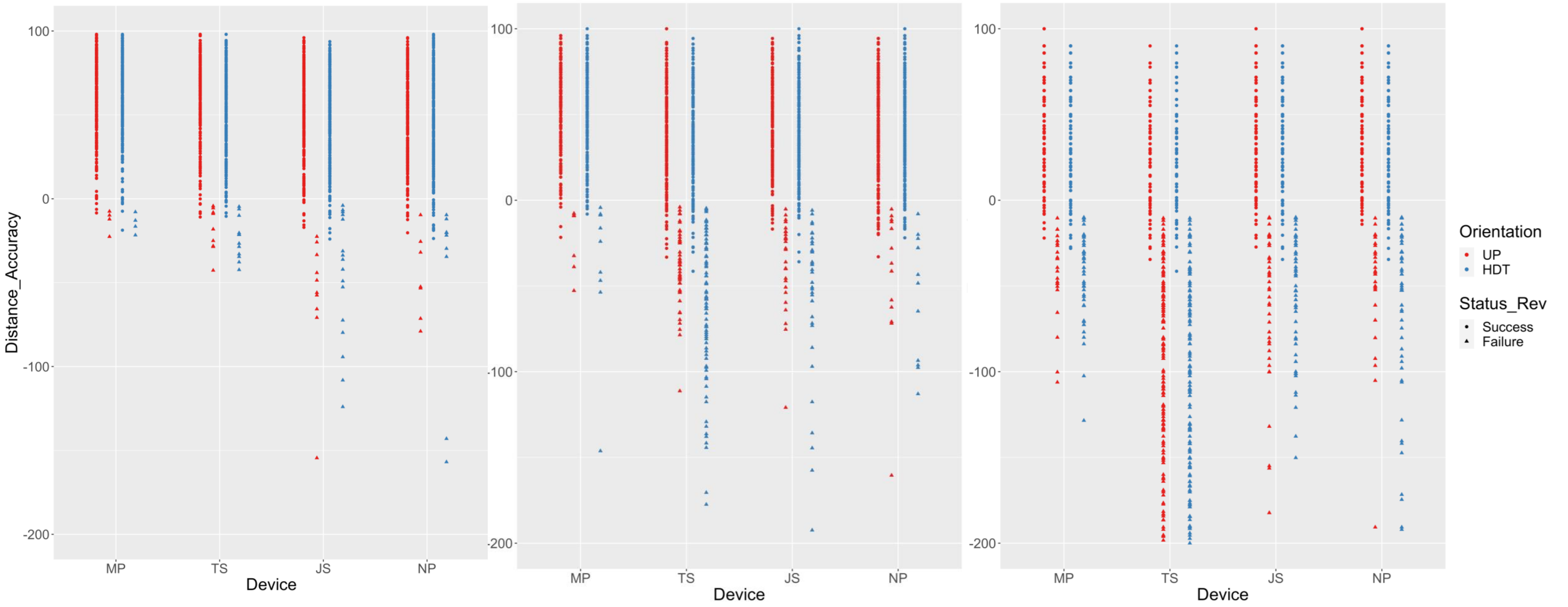
Keypad

NUM LOCK
/
*
BACK SPACE
7
HOME
8
9
PG UP
-
4
5
6
+
1
END
2
3
PG DN
ENTER
0
INS
.
DEL



Orientation: UP Device: NP
Orientation: HDT Device: NP
Accuracy [%]
100
75
50
25
0
0
2
4
6
8
Effective Index of Difficulty
Effective Index of Difficulty
Difficulty
Easy
Medium
Hard

Accuracy Comparison

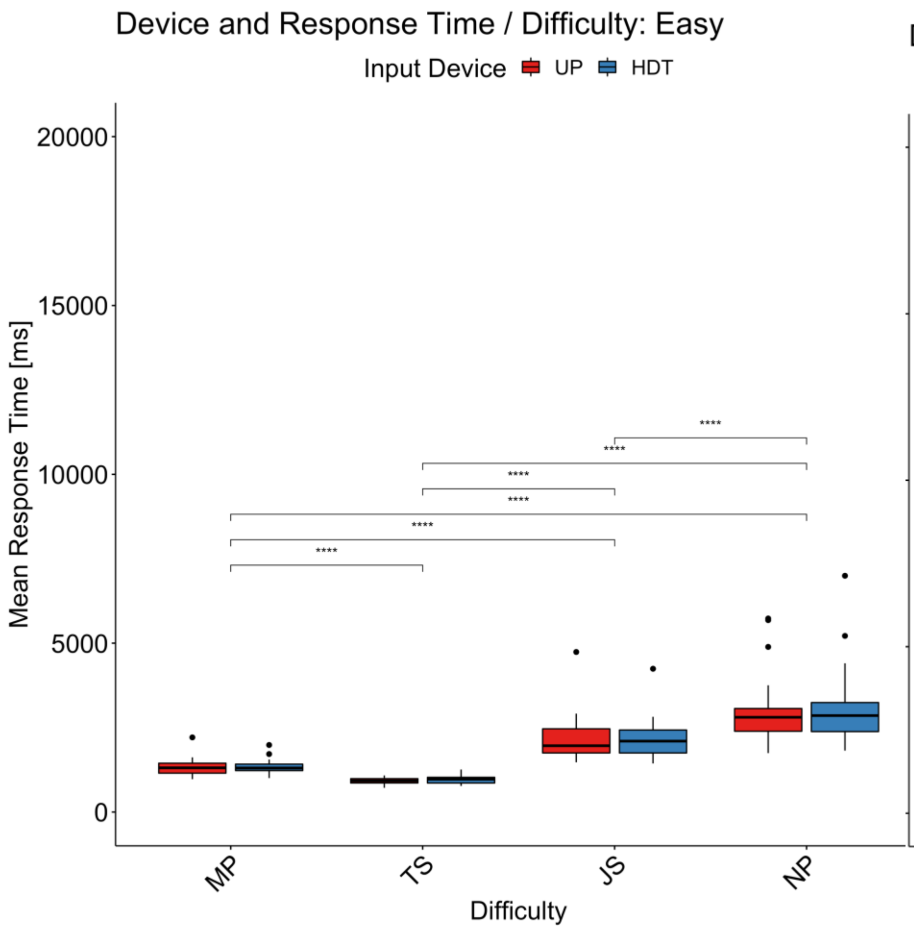


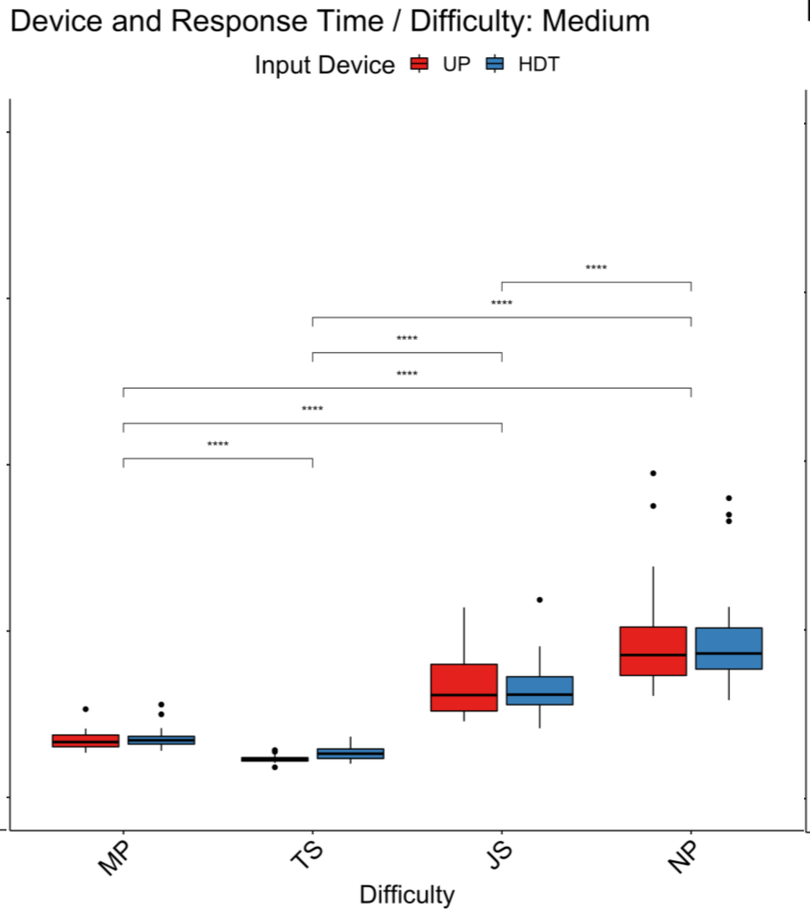
Easy

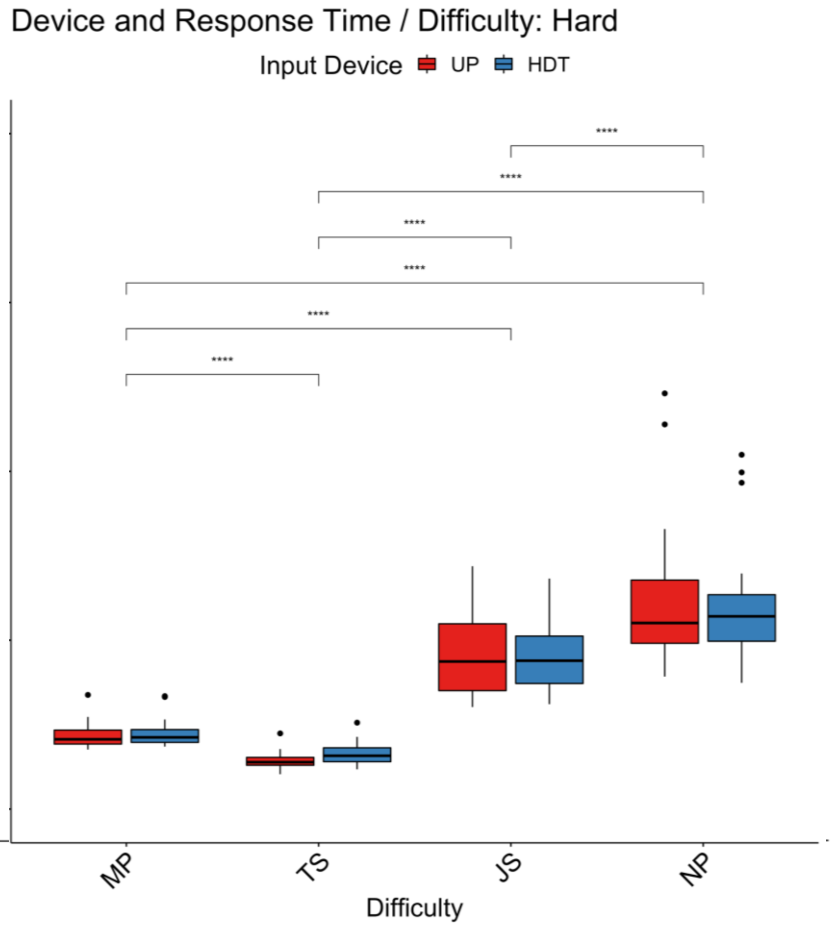
Medium

Hard

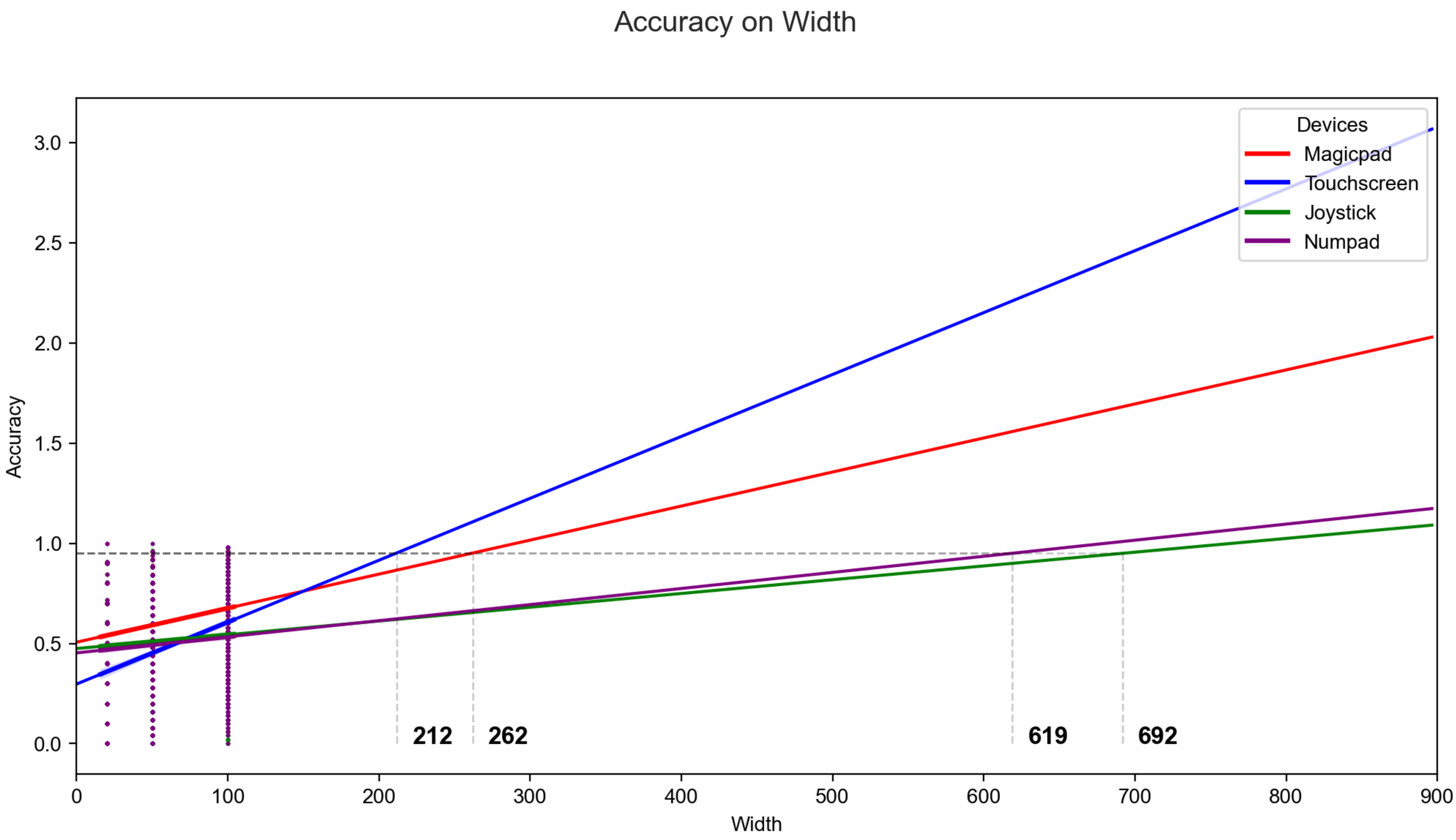
Response Time Comparison







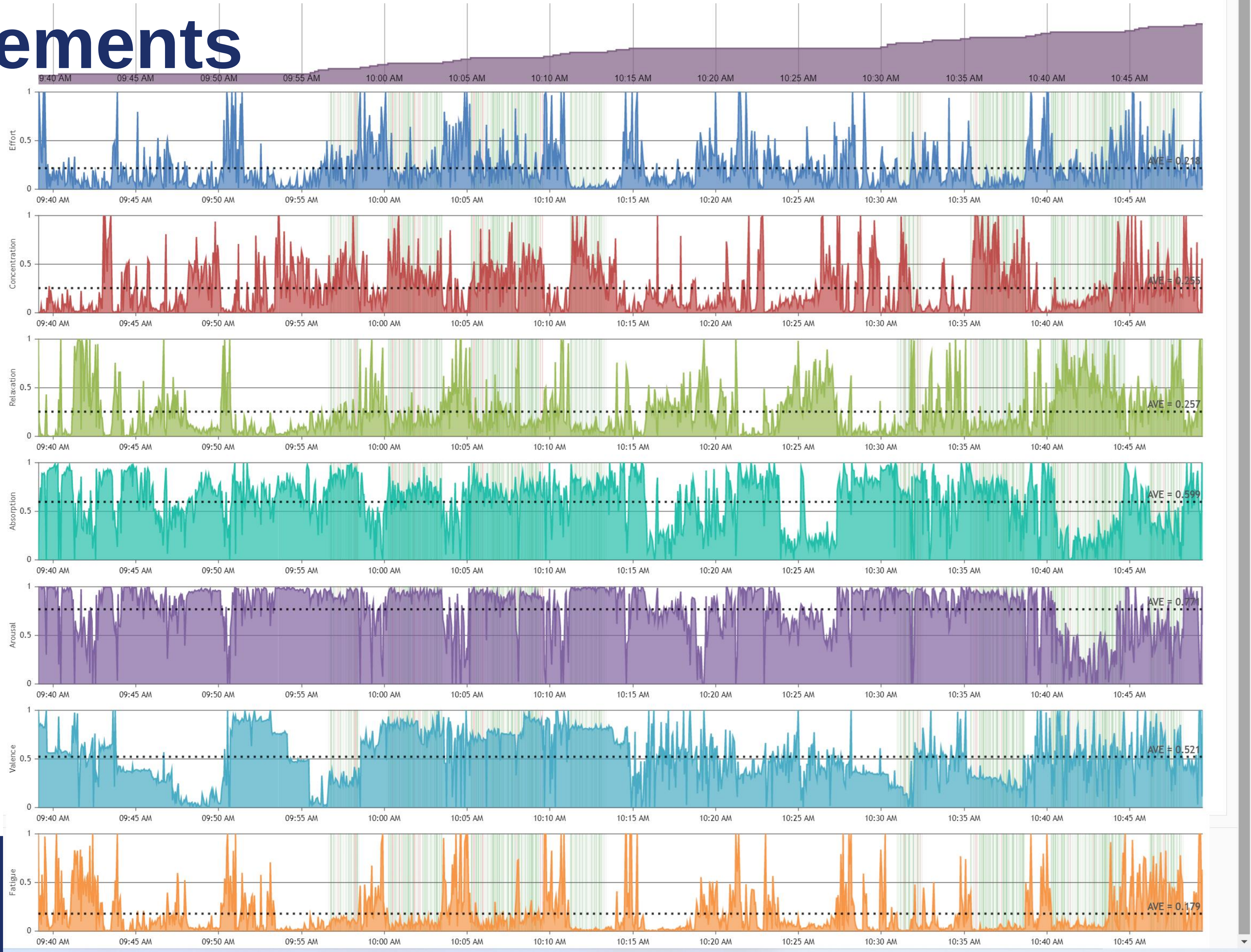
Easy Medium Hard



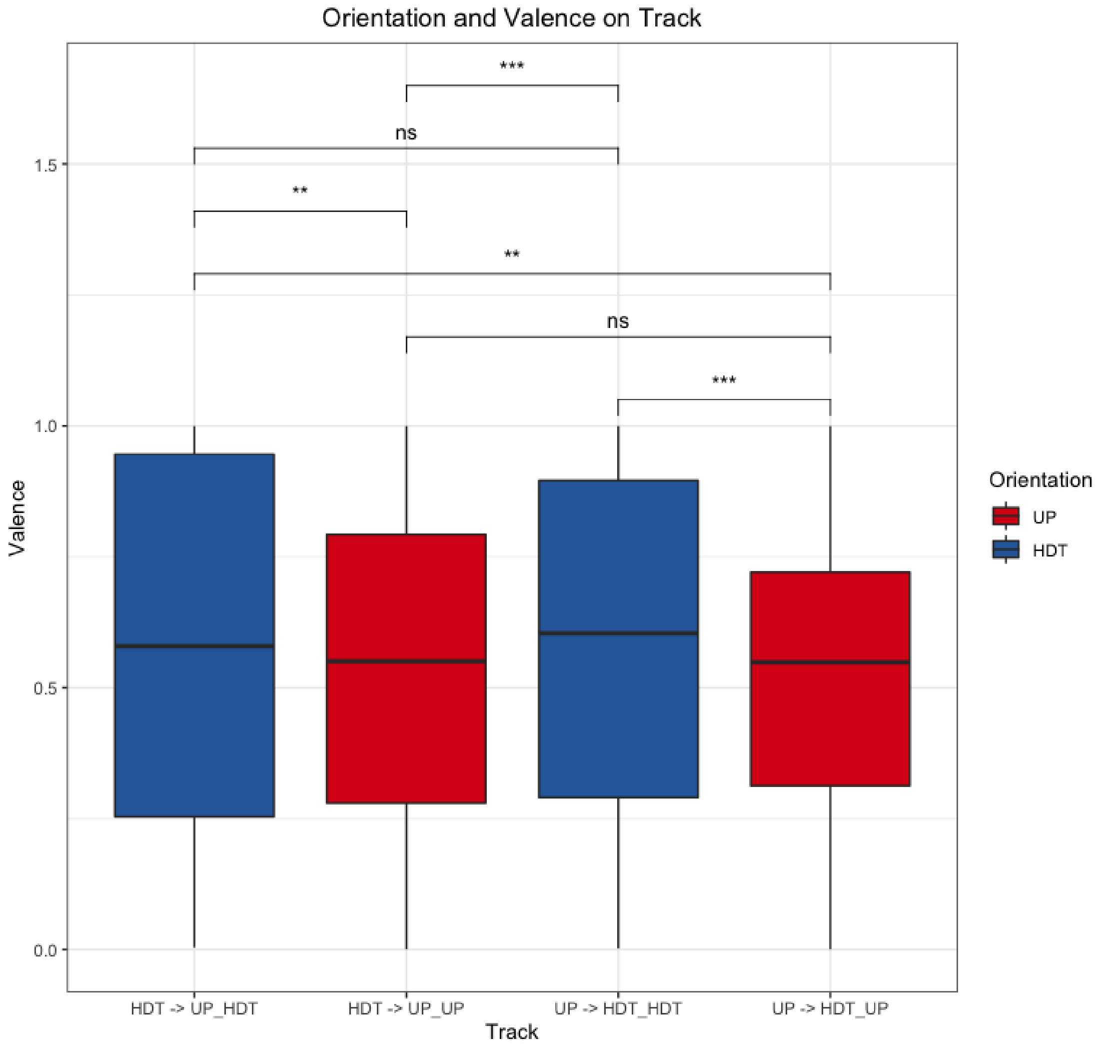
Accuracy on Width
Devices
Magicpad
Touchscreen
Joystick
Numpad
Accuracy
Width
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
100
200
300
400
500
600
700
800
900
212
262
619
692

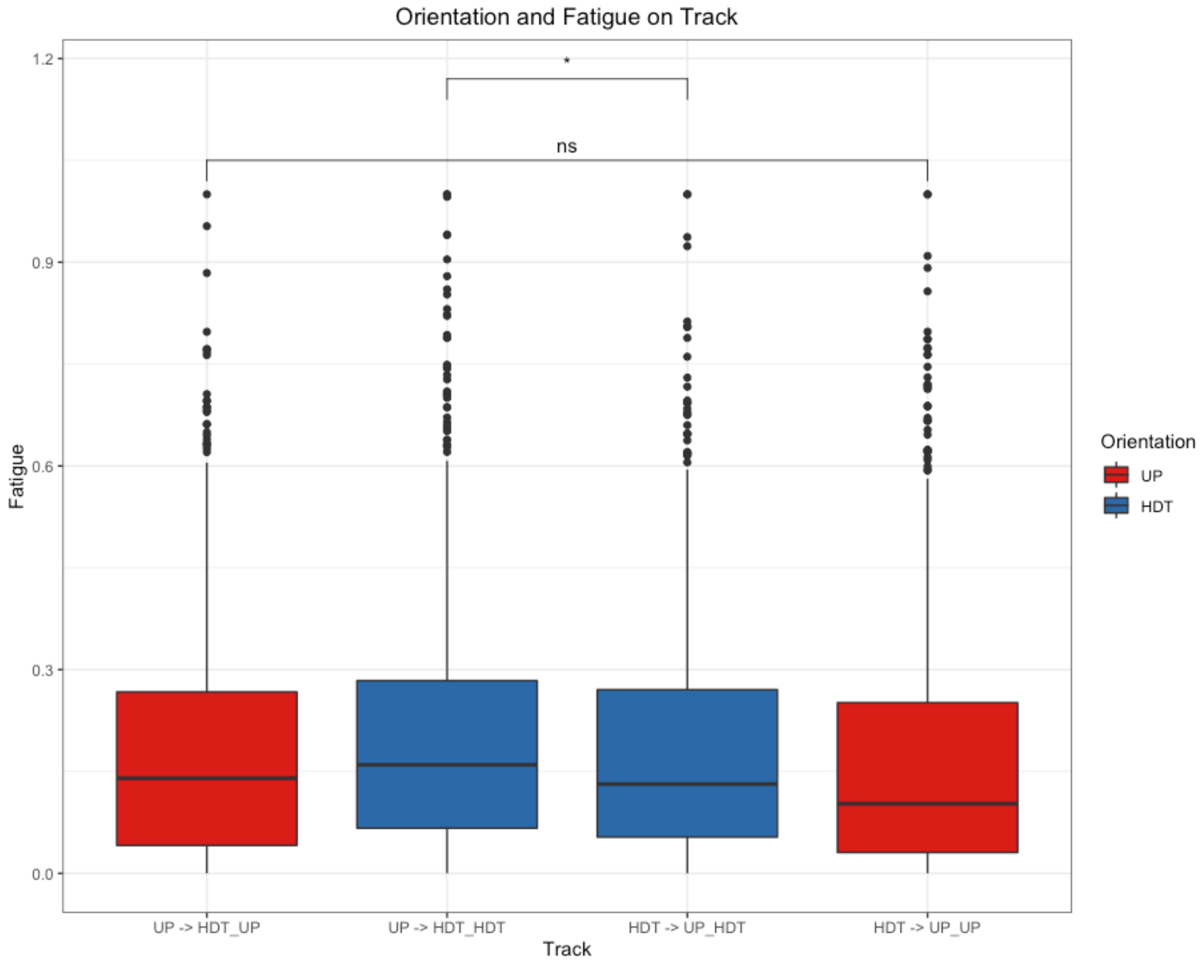
EEG Measurements

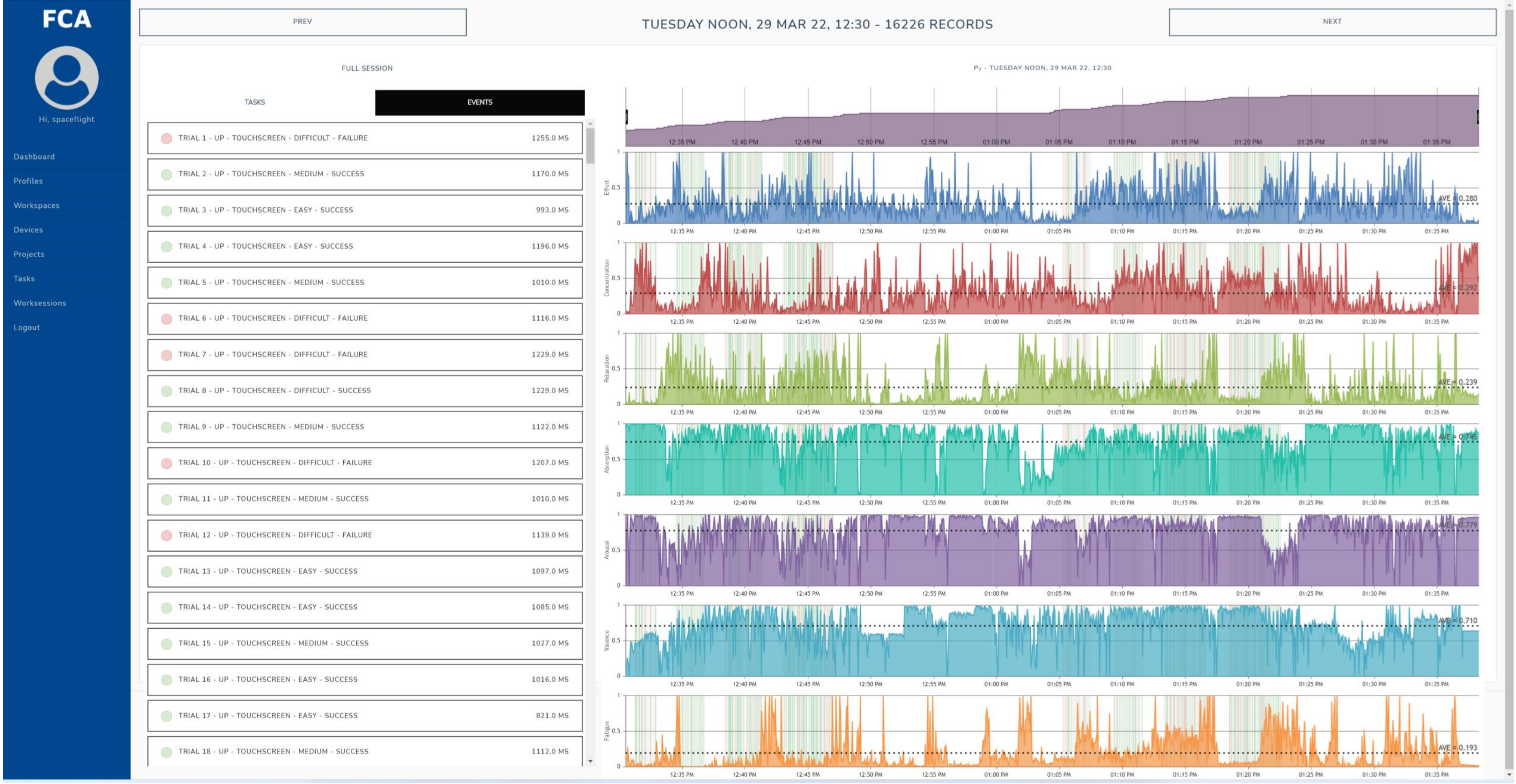
- Signals are processed into cognitive state indicators
- Shaded background areas are trial tasks



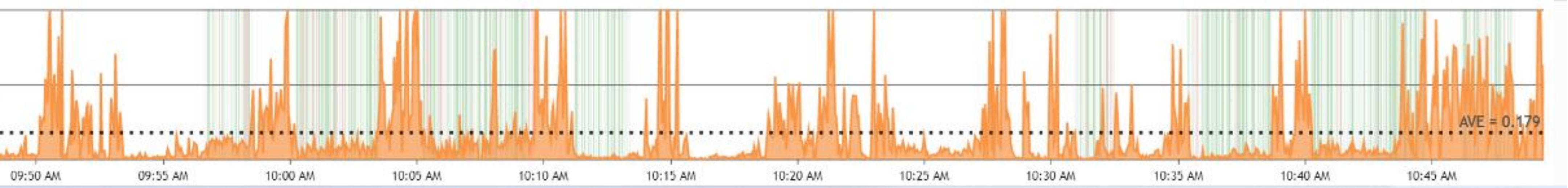
EEG Measurements

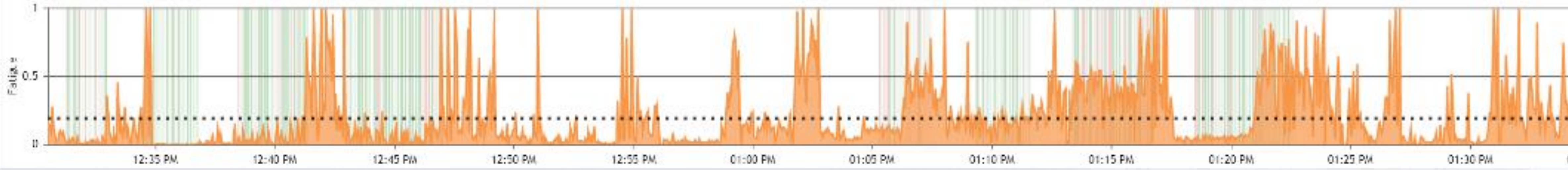




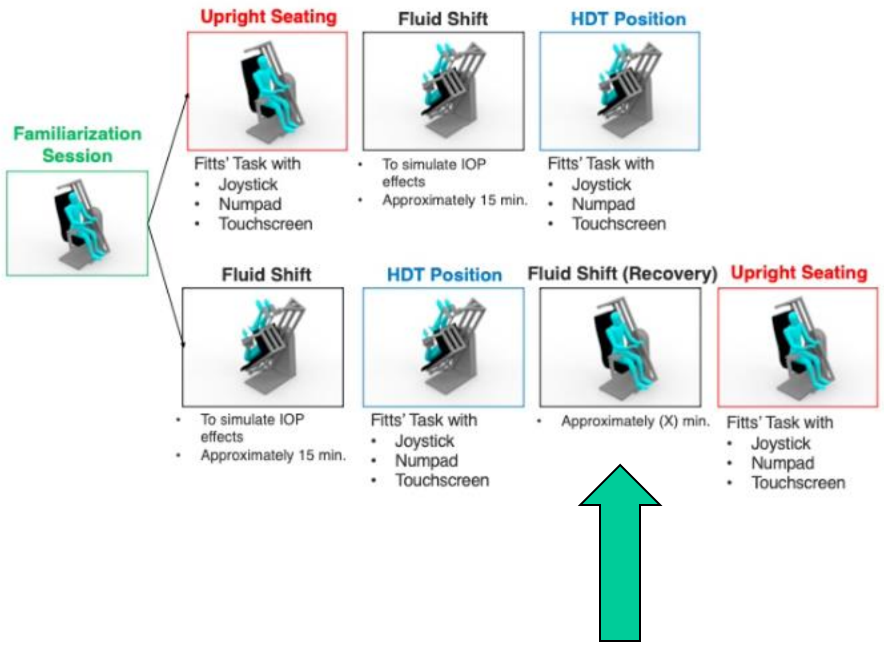

FCA
Hi, spaceflight
Dashboard
Profiles
Workspaces
Devices
Projects
Tasks
Worksessions
Logout
PREV
TUESDAY NOON, 29 MAR 22, 12:30 - 16226 RECORDS
NEXT
FULL SESSION
TASKS
EVENTS
TRIAL 1 - UP - TOUCHSCREEN - DIFFICULT - FAILURE 1255.0 MS
TRIAL 2 - UP - TOUCHSCREEN - MEDIUM - SUCCESS 1170.0 MS
TRIAL 3 - UP - TOUCHSCREEN - EASY - SUCCESS 993.0 MS
TRIAL 4 - UP - TOUCHSCREEN - EASY - SUCCESS 1196.0 MS
TRIAL 5 - UP - TOUCHSCREEN - MEDIUM - SUCCESS 1010.0 MS
TRIAL 6 - UP - TOUCHSCREEN - DIFFICULT - FAILURE 1116.0 MS
TRIAL 7 - UP - TOUCHSCREEN - DIFFICULT - FAILURE 1229.0 MS
TRIAL 8 - UP - TOUCHSCREEN - DIFFICULT - SUCCESS 1229.0 MS
TRIAL 9 - UP - TOUCHSCREEN - MEDIUM - SUCCESS 1122.0 MS
TRIAL 10 - UP - TOUCHSCREEN - DIFFICULT - FAILURE 1207.0 MS
TRIAL 11 - UP - TOUCHSCREEN - MEDIUM - SUCCESS 1010.0 MS
TRIAL 12 - UP - TOUCHSCREEN - DIFFICULT - FAILURE 1139.0 MS
TRIAL 13 - UP - TOUCHSCREEN - EASY - SUCCESS 1097.0 MS
TRIAL 14 - UP - TOUCHSCREEN - EASY - SUCCESS 1085.0 MS
TRIAL 15 - UP - TOUCHSCREEN - MEDIUM - SUCCESS 1027.0 MS
TRIAL 16 - UP - TOUCHSCREEN - EASY - SUCCESS 1016.0 MS
TRIAL 17 - UP - TOUCHSCREEN - EASY - SUCCESS 821.0 MS
TRIAL 18 - UP - TOUCHSCREEN - MEDIUM - SUCCESS 1112.0 MS
P7 - TUESDAY NOON, 29 MAR 22, 12:30
12:35 PM
12:40 PM
12:45 PM
12:50 PM
12:55 PM
01:00 PM
01:05 PM
01:10 PM
01:15 PM
01:20 PM
01:25 PM
01:30 PM
01:35 PM
Effort
AVE = 0.280
Concentration
AVE = 0.292
Relaxation
AVE = 0.239
Absorption
AVE = 0.745
Arousal
AVE = 0.779
Valence
AVE = 0.710
Fatigue
AVE = 0.193

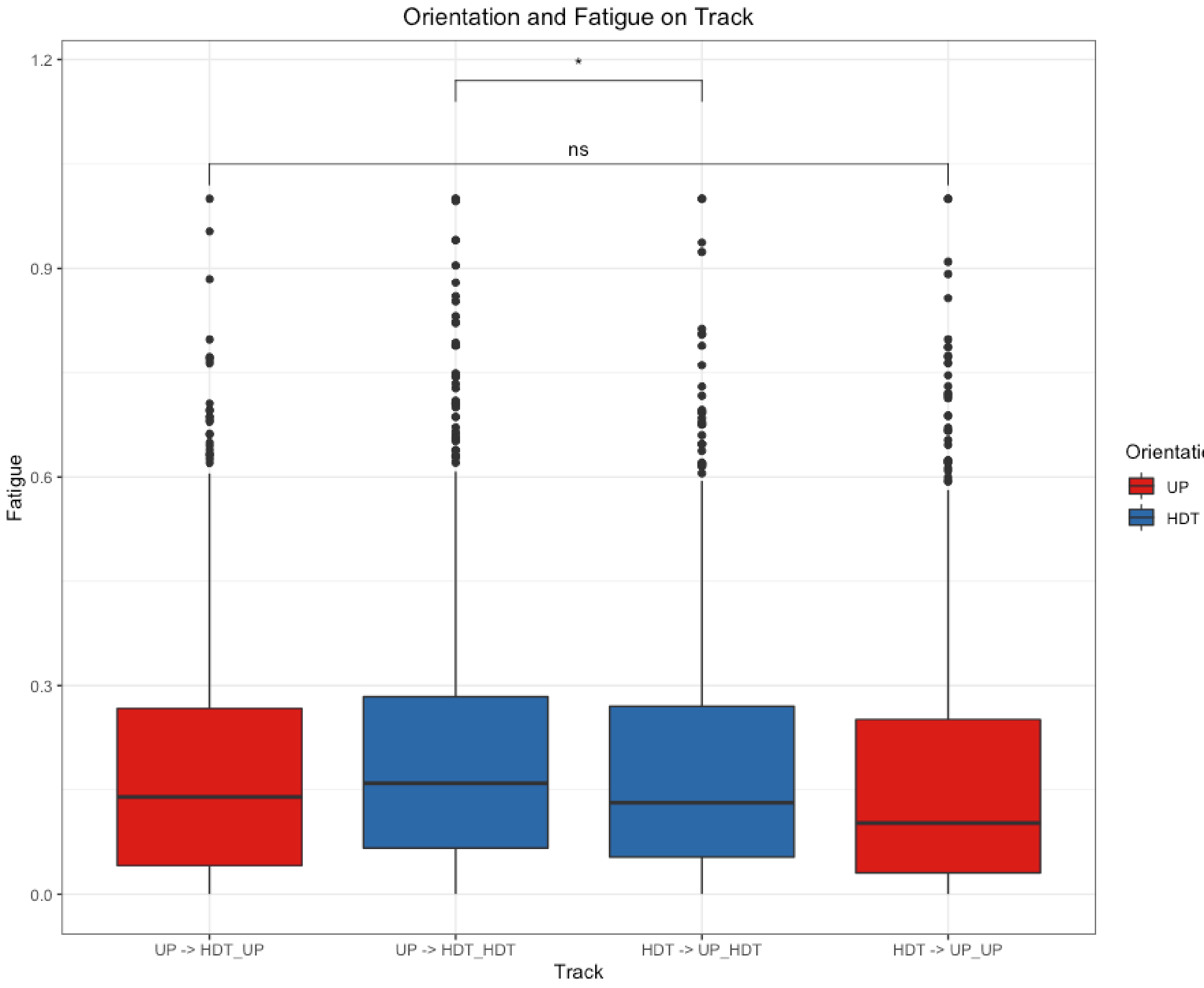
Fatigue during trials





Limitations of the Study





Publications, Presentations, Awards, & Recognitions

RELATED PUBLICATIONS

Momose, K., Weekes, T.R., and Eskridge, T.C.(2021). Human-Centered Design for Spaceflight Participant Safety and Experience: A Case Study of Blue Origin Suborbital Flight. *New Space Journal*, online 11 Nov 2021. https://doi.org/10.1089/space.2021.0029

https://www.liebertpub.com/doi/10.1089/space.2021.0029

NEW SPACE
Preprint, 2021

https://doi.org/10.1089/space.2021.0029

Mary Ann Liebert, Inc. publishers

Original Article

Human-Centered Design for Spaceflight Participant Safety and Experience: A Case Study of Blue Origin Suborbital Flight

.

Kazuhiko Momose[1], Troy R. Weekes[1], and Thomas C. Eskridge[1,2]

Conclusions and Future Work

- This approach allows for inclusion of speed and accuracy in determining size/distance recommendations
- Differences in HDT mean that designs need to include microgravity differences in perception
- Testing also reveals the effects of fatigue on speed and accuracy, which can enable adaptive automation
- Collecting in-suit trials
- Continuing to analyze data
- Final reporting and publication