

Quantifying 3D Pointing: Characterizing What Happens During Pointing Selection in Virtual Reality

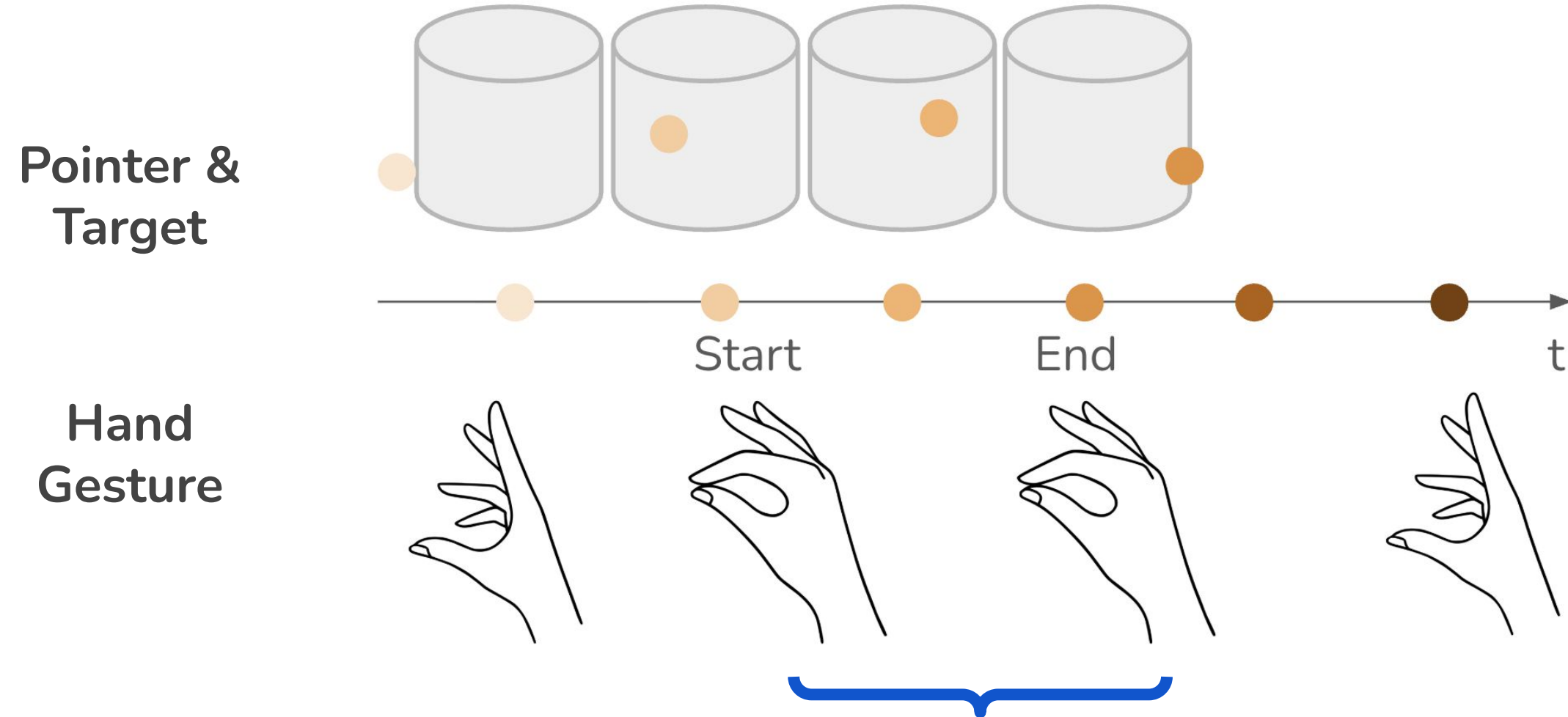


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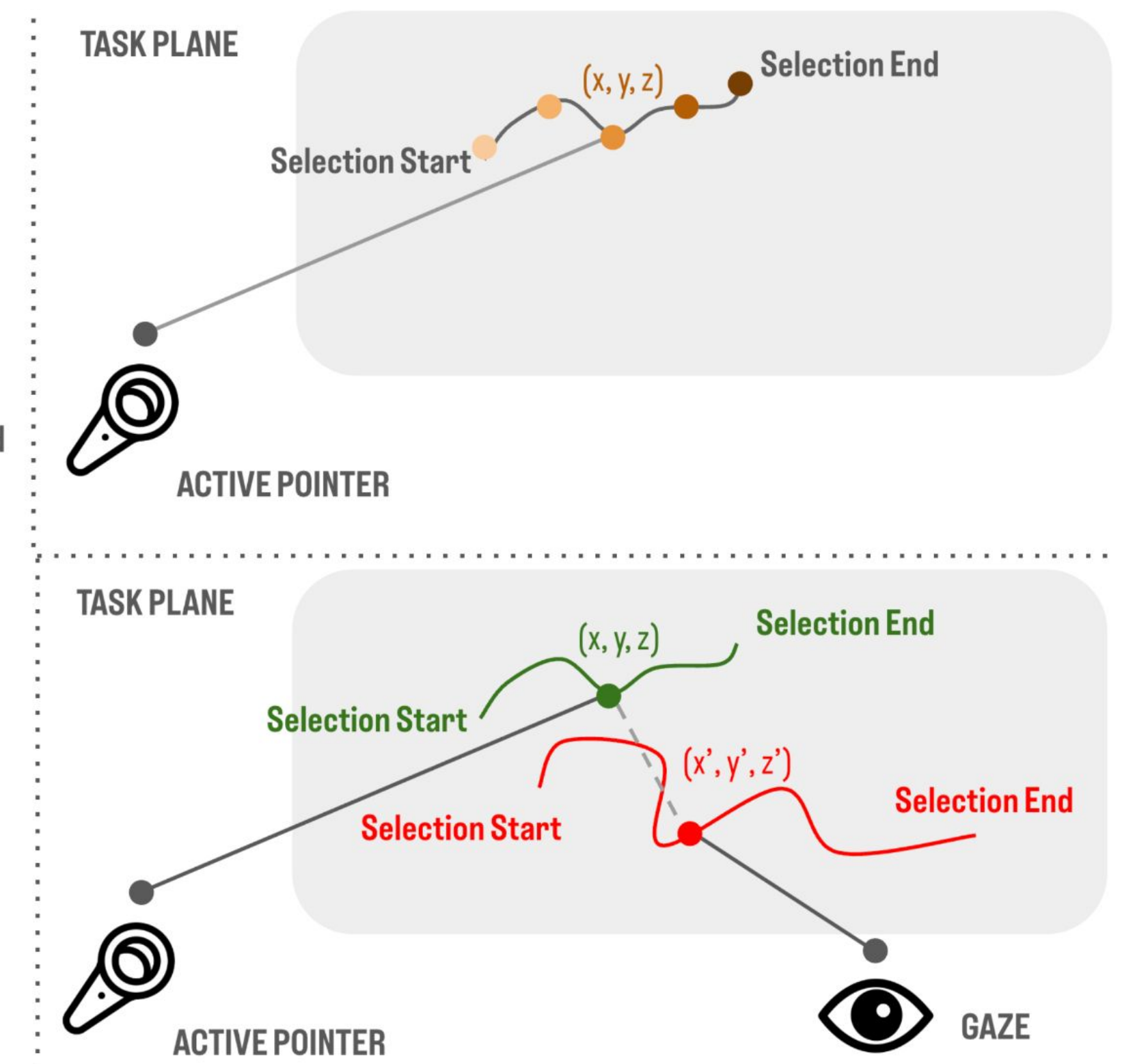
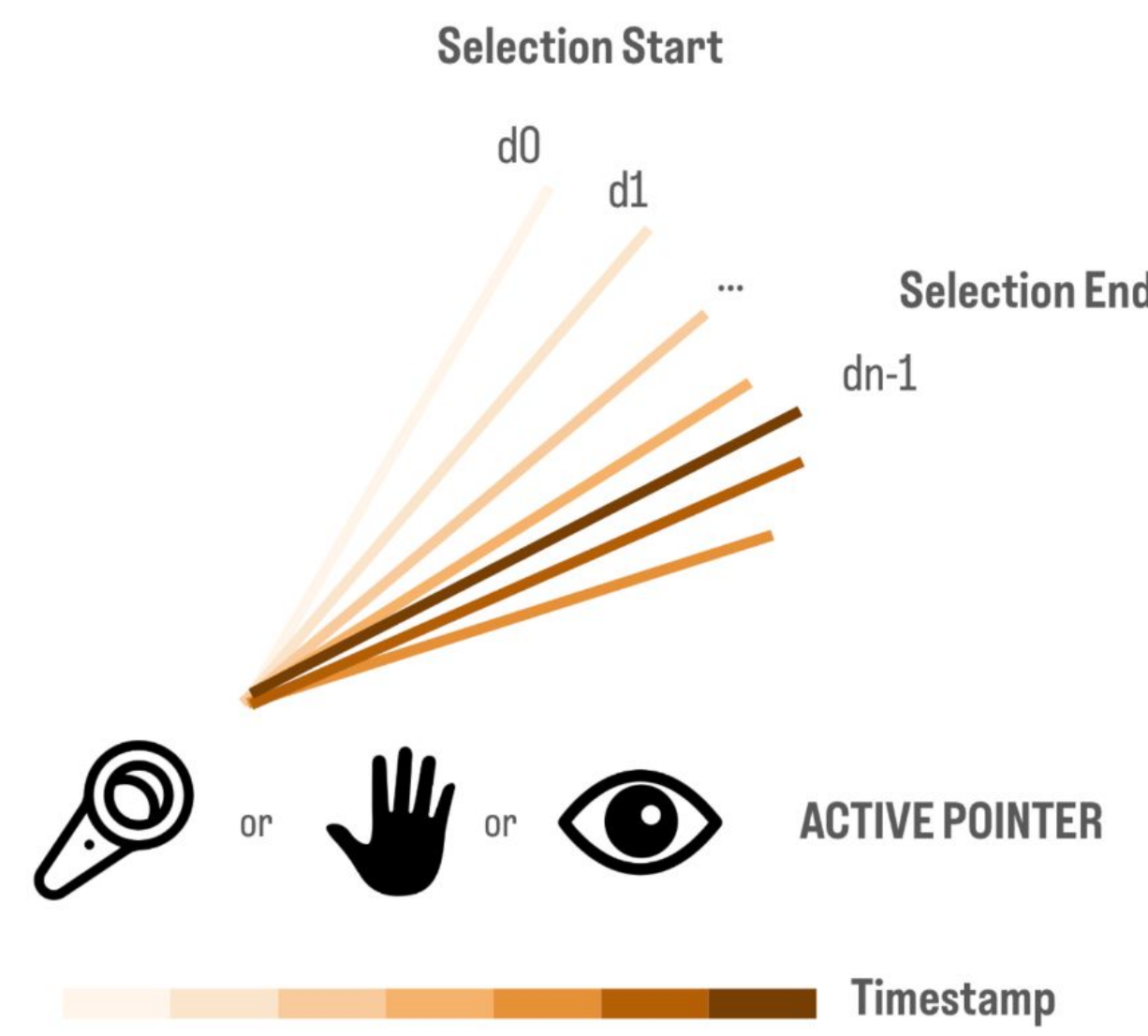
MOTIVATION

A pointing selection process is not **atomic**



- What happens “**during**” pointing selection?
- Can we use the **pointer movement & user behavior** during this time to characterize pointing **performance & user experience**?

ANATOMY OF 3D POINTING



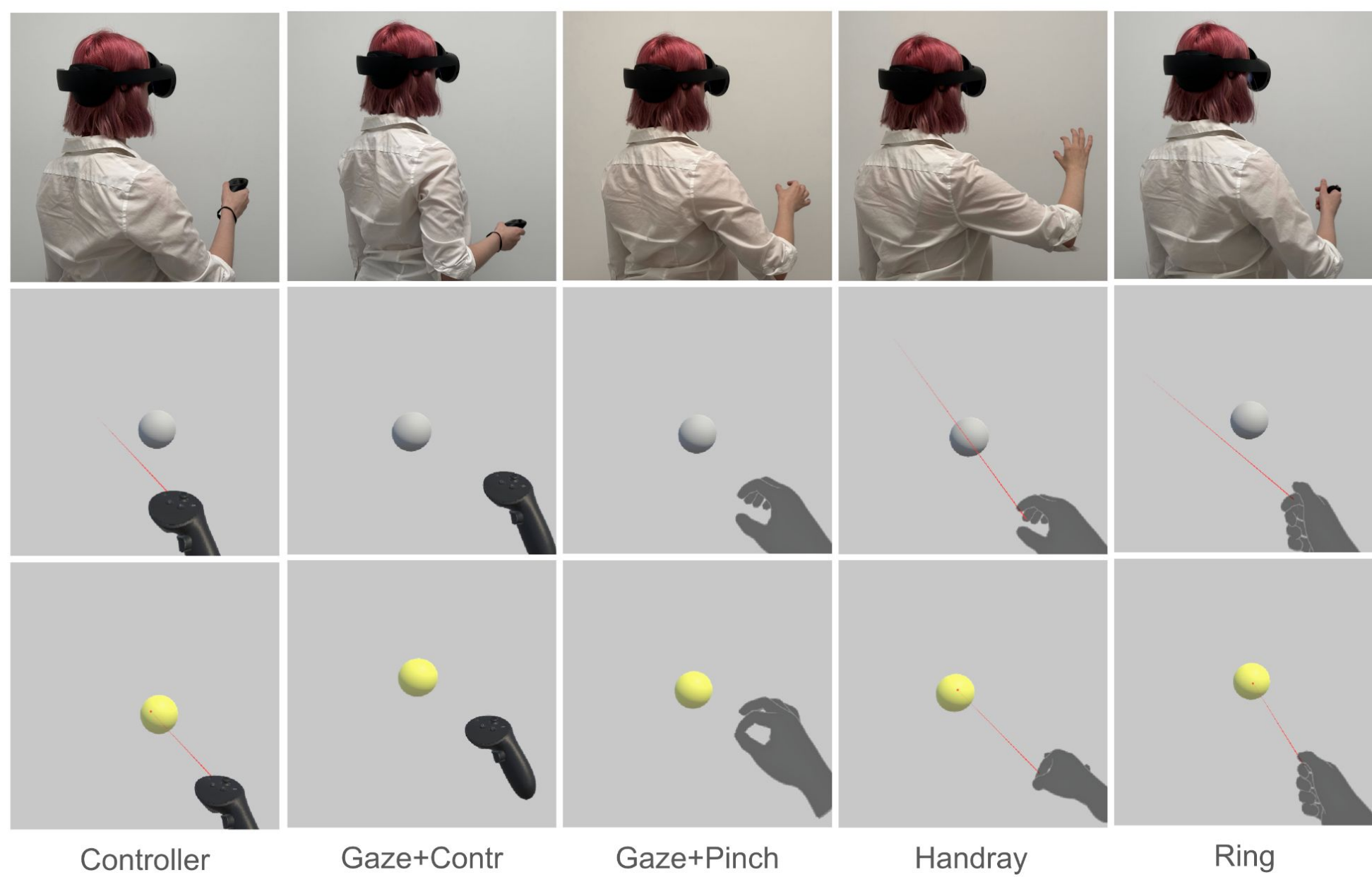
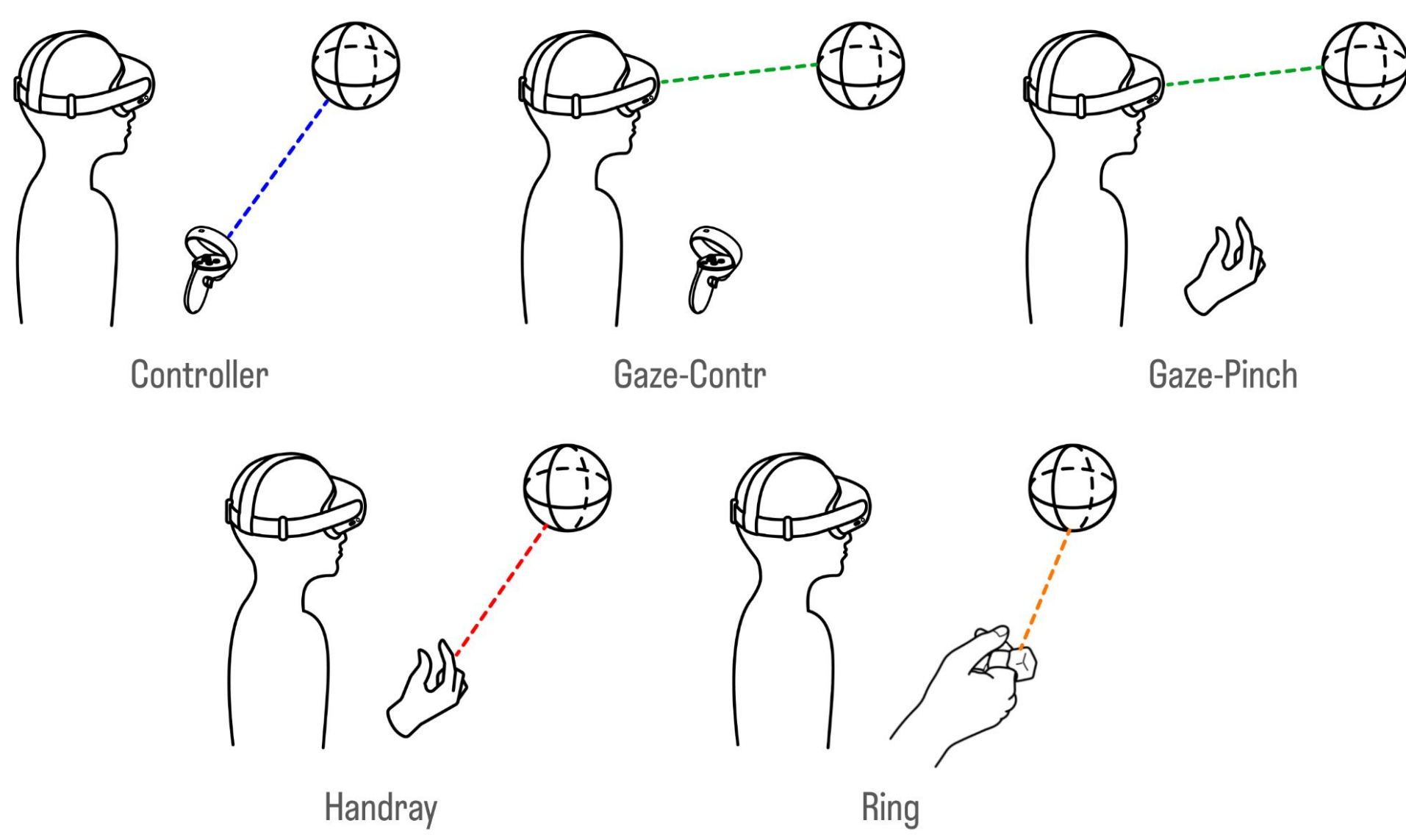
Check out our paper!

OUR MEASURES

POINTER MOVEMENT		USER BEHAVIOR – SINGLE MODALITY				ALIGNMENT BETWEEN MODALITIES	
Pointer Direction Variability	Hit Point Variability	Gaze Direction Range	Head Direction Range	Palm Position Drift	Index Fingertip Variability	Mean Alignment Distance	Alignment-Adjusted Endpoint
$\sum_{i=1}^n \Delta(d_{i-1}, d_i)$	$\sum_{i=1}^n D(\text{Hit}_{i-1}, \text{Hit}_i)$	$\max_{i,j} \Delta(d_{g,i}, d_{g,j})$	$\max_{i,j} \Delta(d_{h,i}, d_{h,j})$	$D(P_0, P_{n_p-1})$	$\sum_{i=1}^n D(f_{i-\text{idx}}, f_{i\text{idx}})$	$\frac{1}{n} \sum_{i=1}^n D(\text{Hit}_i, \text{Hit}'_i)$	(X^*, Y^*, Z^*) $i^* = \text{argmin}_{i \in \{1, \dots, n\}} D(\text{Hit}_i, \text{Hit}'_i)$
How “jittery” the pointing direction was.	How “jittery” the pointer was on the task plane .	How far the eyes swept during selection.	How much the head turned during selection.	How far the hand moved from where it started.	How much the fingertip moved during the gesture.	How closely gaze and pointer stayed aligned.	Where the pointer was when alignment was closest .
Notation. $\Delta(\cdot, \cdot)$ angle between two directions $D(\cdot, \cdot)$ Euclidean distance Hit_i pointer hit point Hit'_i gaze hit point n, n_g, n_h, n_p, n_f sample counts (pointer, gaze, head, palm, fingertip)							

EXPERIMENT

5 **Techniques** x 2 **Target Sizes**
36 participants, within-subject
14112 total trials collected



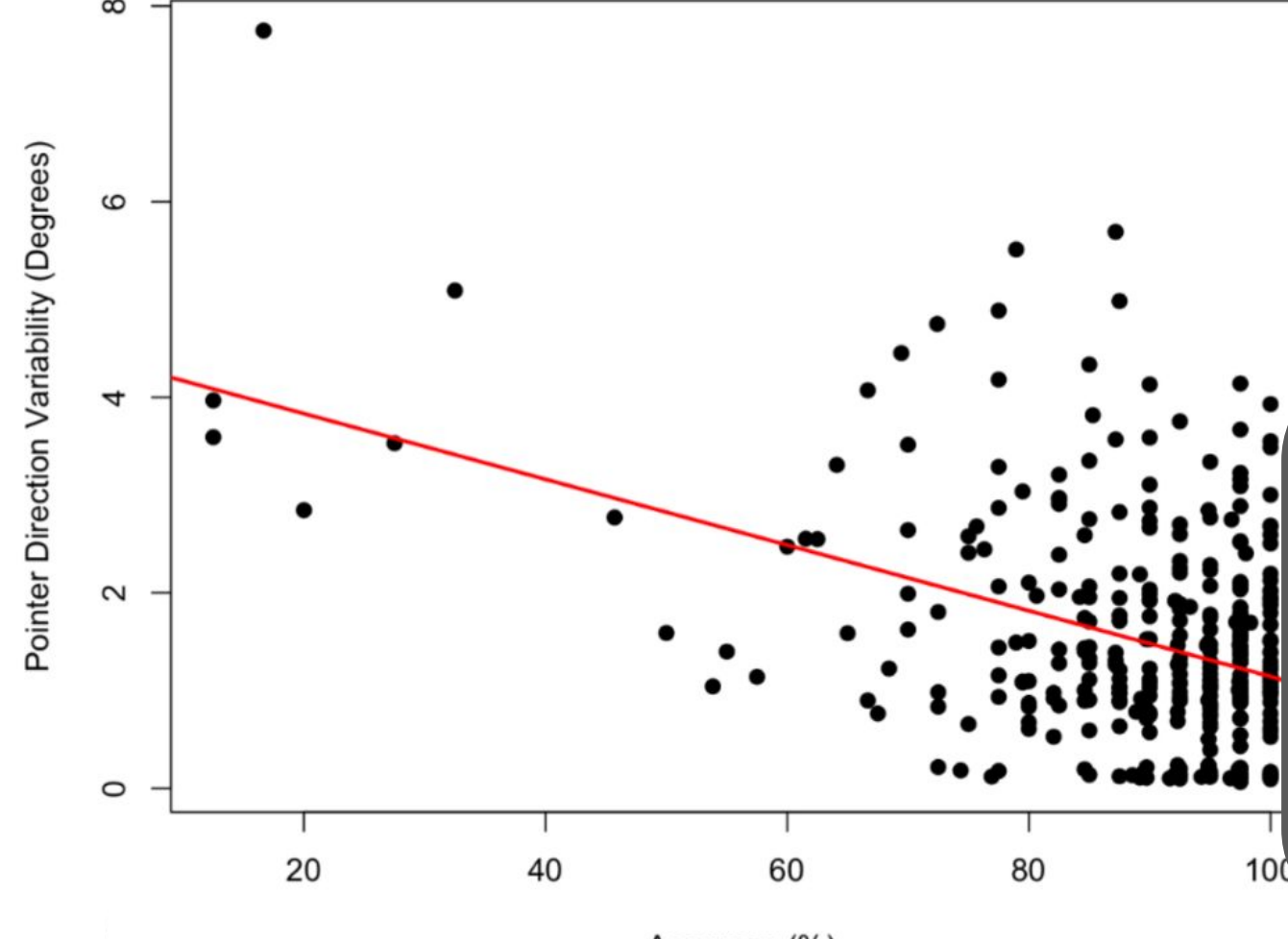
FINDINGS

1) Our measures are correlated with task load, perceived exertion, and other usability measures

2) Speed has a larger effect on overall performance than accuracy

- Lower measure values (i.e., more “stable” pointing) ~ higher pointing accuracy
- Yet higher measure values (i.e. less “stable” pointing) ~ higher throughput

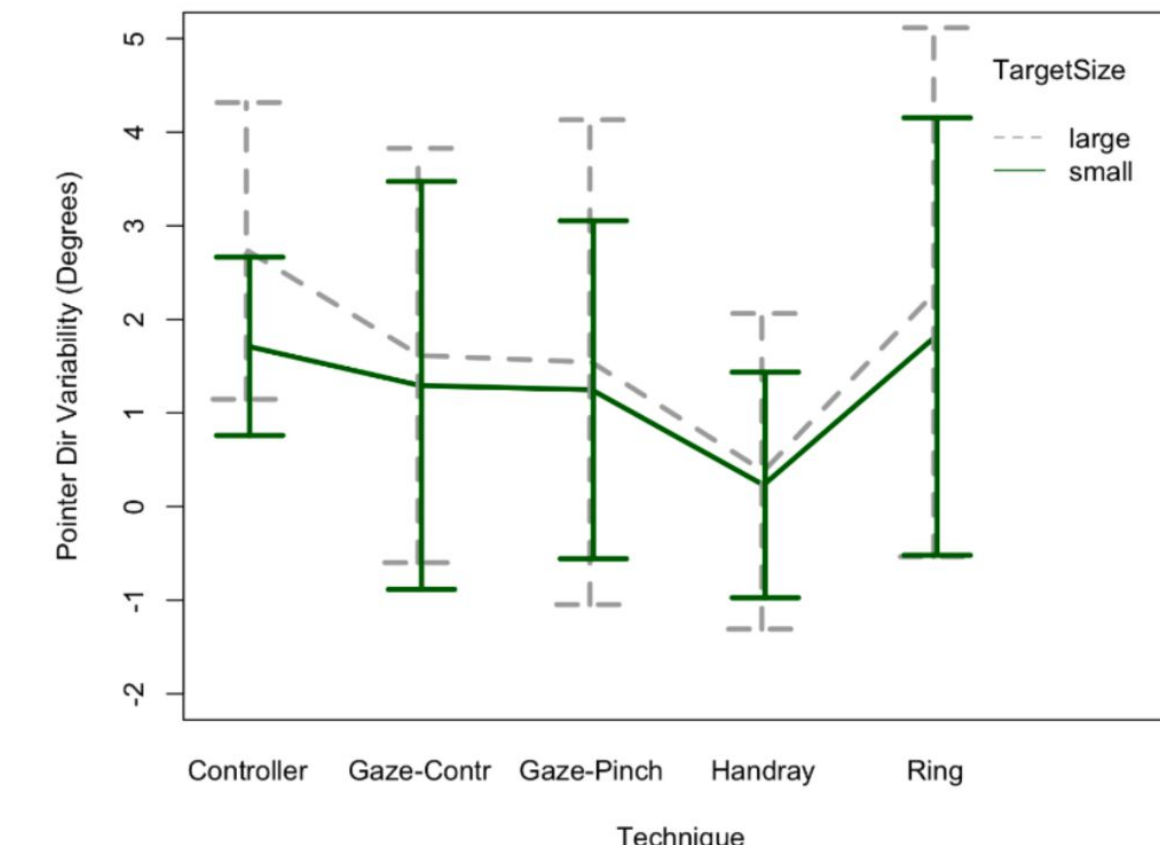
Pointer Dir Variability ~ Accuracy (Block Average)



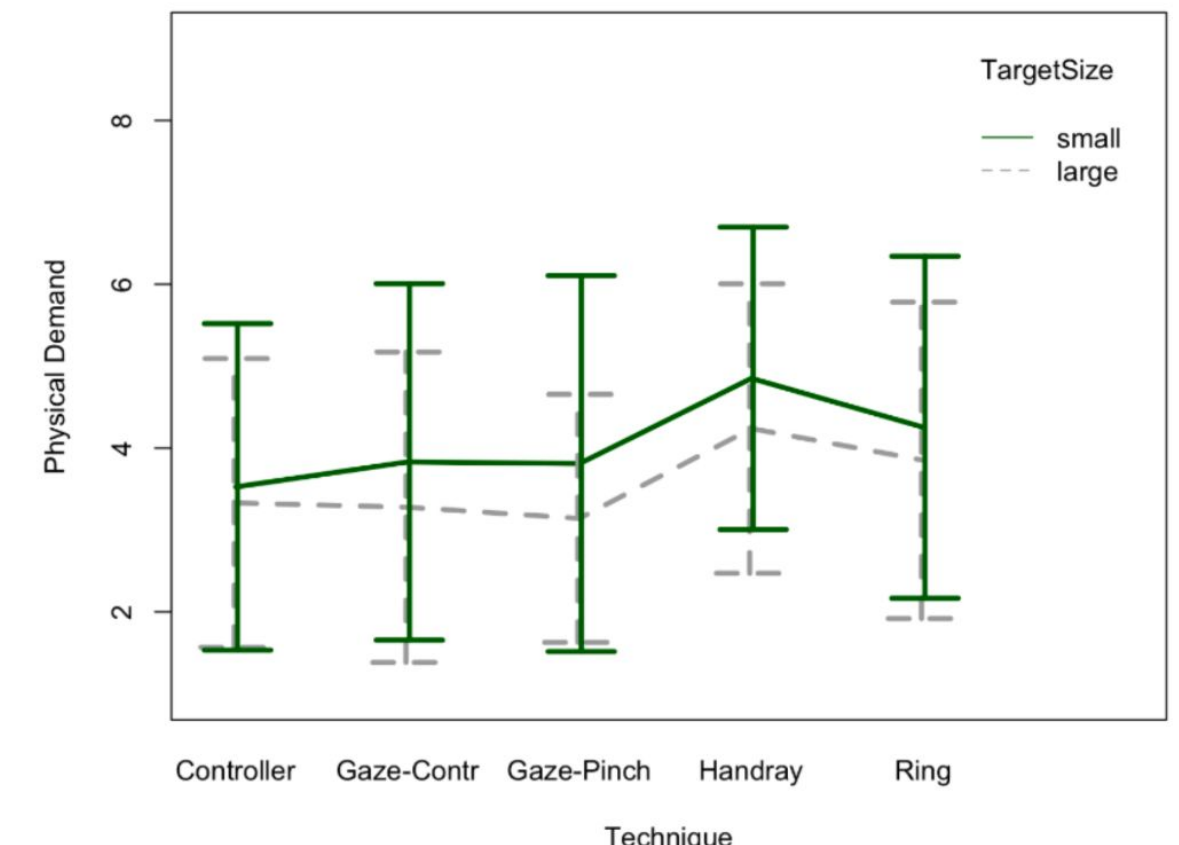
Throughput
Highest: Controller
($M=2.49, SD=0.51$)
Lowest: Handray
($M=1.34, SD=0.27$)

3) Higher tolerance for less “stable” pointing improves the pointing user experience

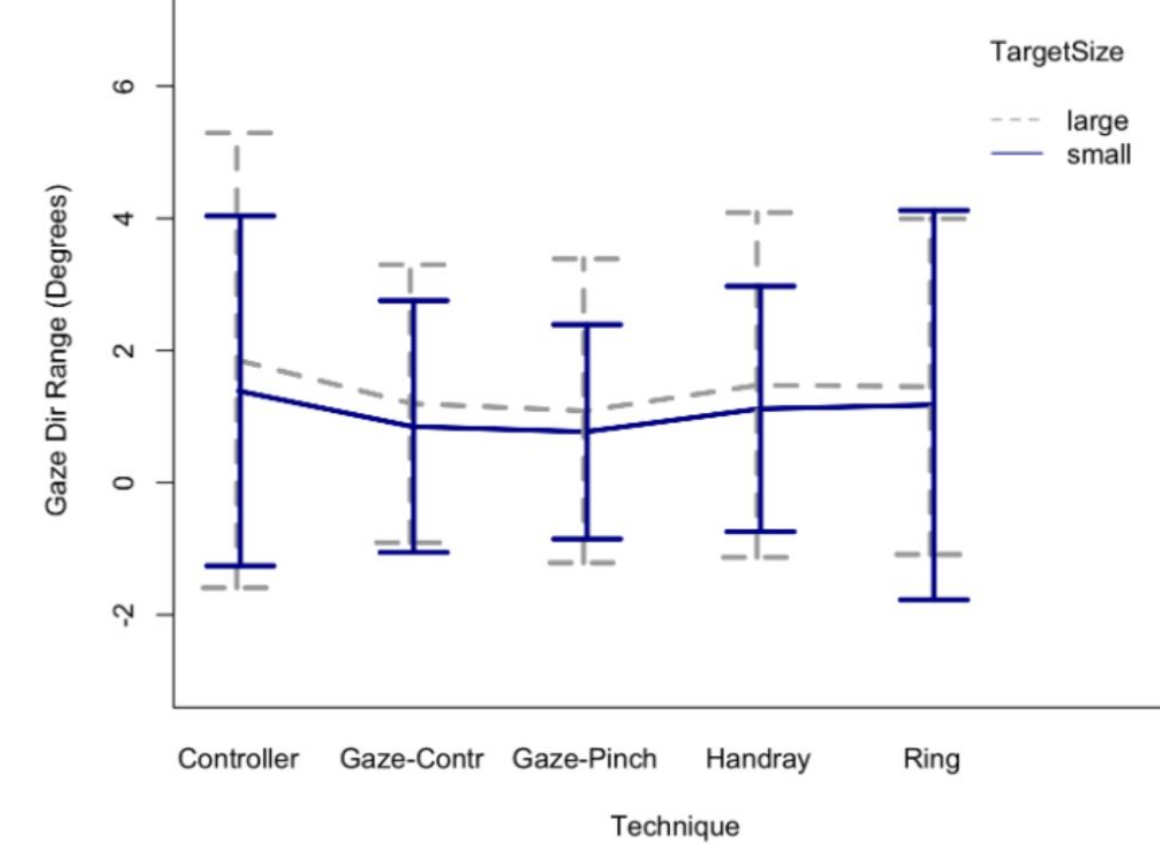
Pointer Dir Variability by Technique, TargetSize



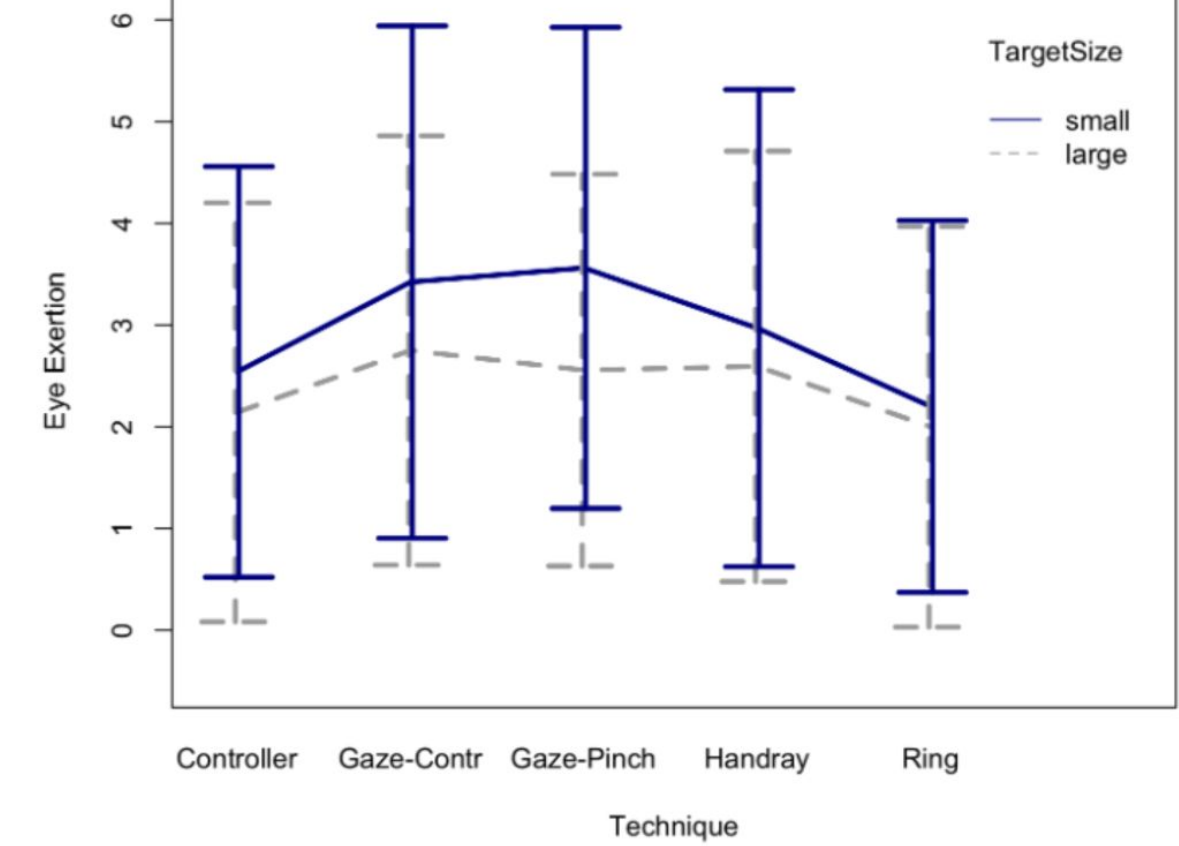
Physical Demand by Technique, TargetSize



Gaze Dir Range by Technique, TargetSize



Eye Exertion by Technique, TargetSize



4) Modalities don’t work in isolation during 3D pointing

- Using **alignment-adjusted endpoints** improves pointing accuracy (91.8% to 93.6%, $p < .01$)

DESIGN IMPLICATIONS

- 3D pointing interactions should
- Improve tolerance for **less “stable”** pointing;
 - Prioritize movement speed over pointing accuracy
 - Prioritize latency over sensing accuracy
 - Consider **coordination** among different modalities

Measure Value	Performance			User Experience Ratings		
	Accuracy	Speed	Throughput	Task Load	Exertion	Additional
High	Low	High *	High *	Low *	Low *	High *
Low	High *	Low	Low	High	High	Low

Higher measure value means more movement during pointing selection

* indicates “better” performance and experience