

# **WRIST:** **Wearables for Rich, Subtle, Gestural** **Interactions in Ubiquitous Environments**

**Edward Lank**

With:

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Keiko Katsuragawa, James Wallace, Dan Vogel, Jaime Ruiz,  
Krzysztof Pietroszek, Matt Negulescu, Ankit Kamal, Alec Azad,  
Shaishav Siddhpuria, Edmund Liu, Jay Henderson

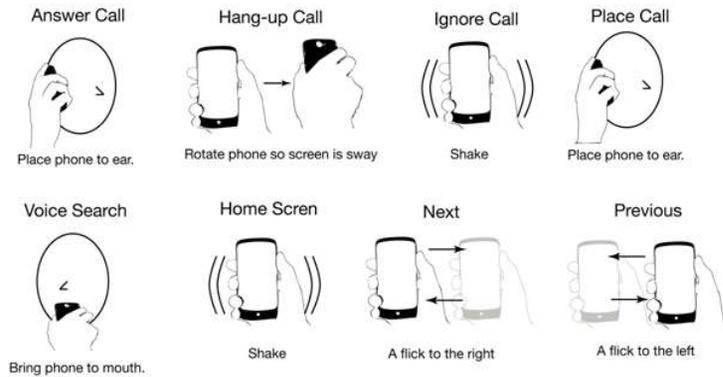
# Motion Gestures

A gesture performed by physically translating or/and rotating the device.

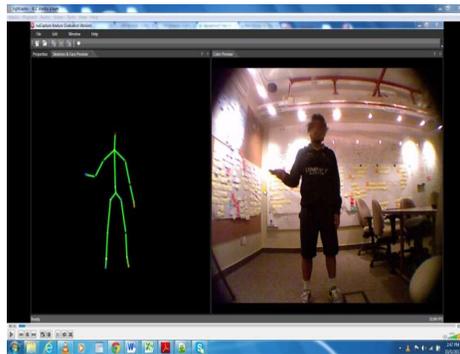


Shake to Shuffle

# Mapping: Motion Gesture Design



# Scaffolding: Training Mechanisms



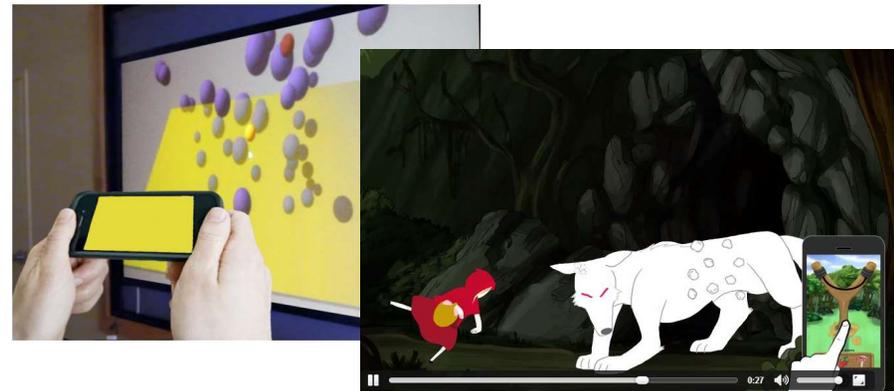
**WATERLOO HCI**  
CHERITON SCHOOL OF COMPUTER SCIENCE

Edward Lank

# Eyes-Free Input: Tap/Swipe/Motion Gestures



# Multi-Display Interactions



# Smartphones + Motion Wearables + Gestures + UBICOMP/IoT



# Killer App for Wearables?

Josh Constantine, "Apple Watch Review: After 2 Months..."

<https://techcrunch.com/2015/07/08/apple-watch-review-after-2-months/>





**Embedded Interaction** is the technological and conceptual phenomena of seamlessly integrating the means for interaction into everyday artifacts.

- Sensing, actuation, processing, and networking.
- Interaction into users' everyday tasks.

- Kranz, Holleis, & Schmidt, (2010). Embedded interaction: Interacting with the internet of things. *IEEE Internet Computing*, 14(2), 46-53.

# Why Wearables?

- Embedded devices (vs interactive devices)
- Invisibility dilemma
- Implicit vs Explicit interaction and the Midas touch phenomenon
- Sensing and tracking

# Beyond being there

by Jim Hollan and Scott Stornetta  
CHI '92

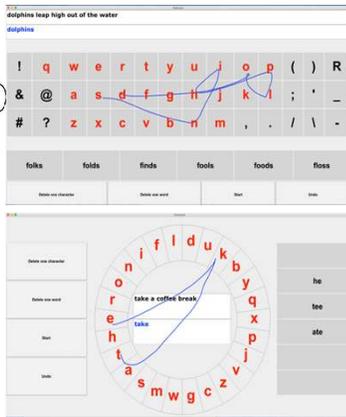
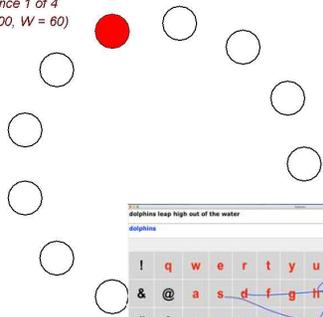
“The mismatch between what we actually have and what we can deliver.”

- Andy Wilson, Graphics Interface 2017 Keynote

# Wearables (Smartwatches) for Rich, Subtle, Gestural Interactions

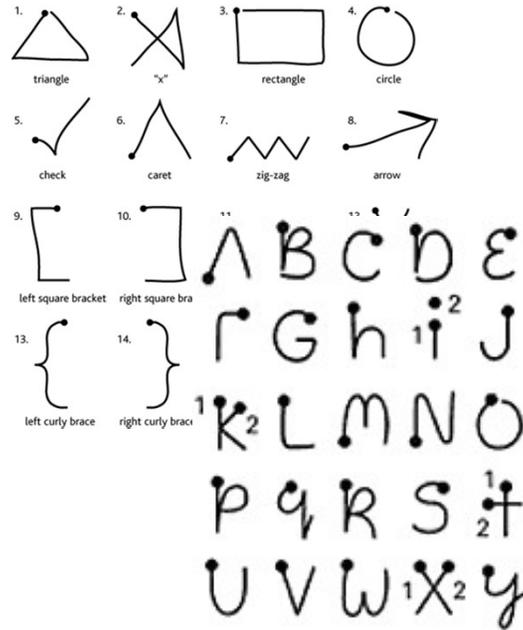
## Manipulation and Text Input

sequence 1 of 4  
= 500, W = 60)



AVI 2016, CHI 2018

## Ideographic Gestures



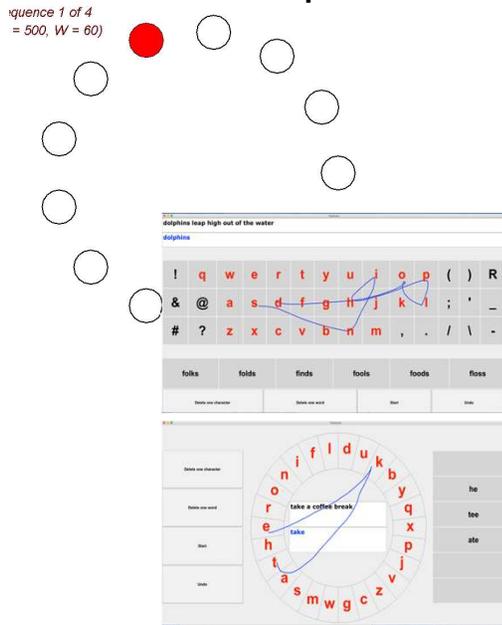
DIS 2017

## Finger Gestures



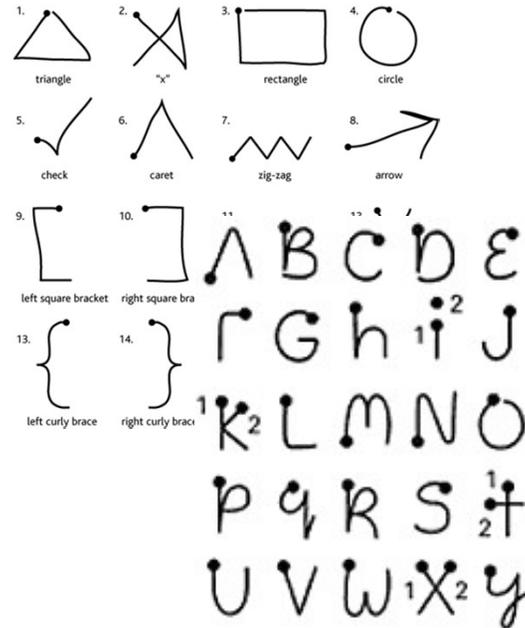
# Wearables for Transient, Subtle, Reliable Interactions

Manipulation and  
Text Input



AVI 2016, CHI 2018

Ideographic Gestures



DIS 2017

Finger Gestures



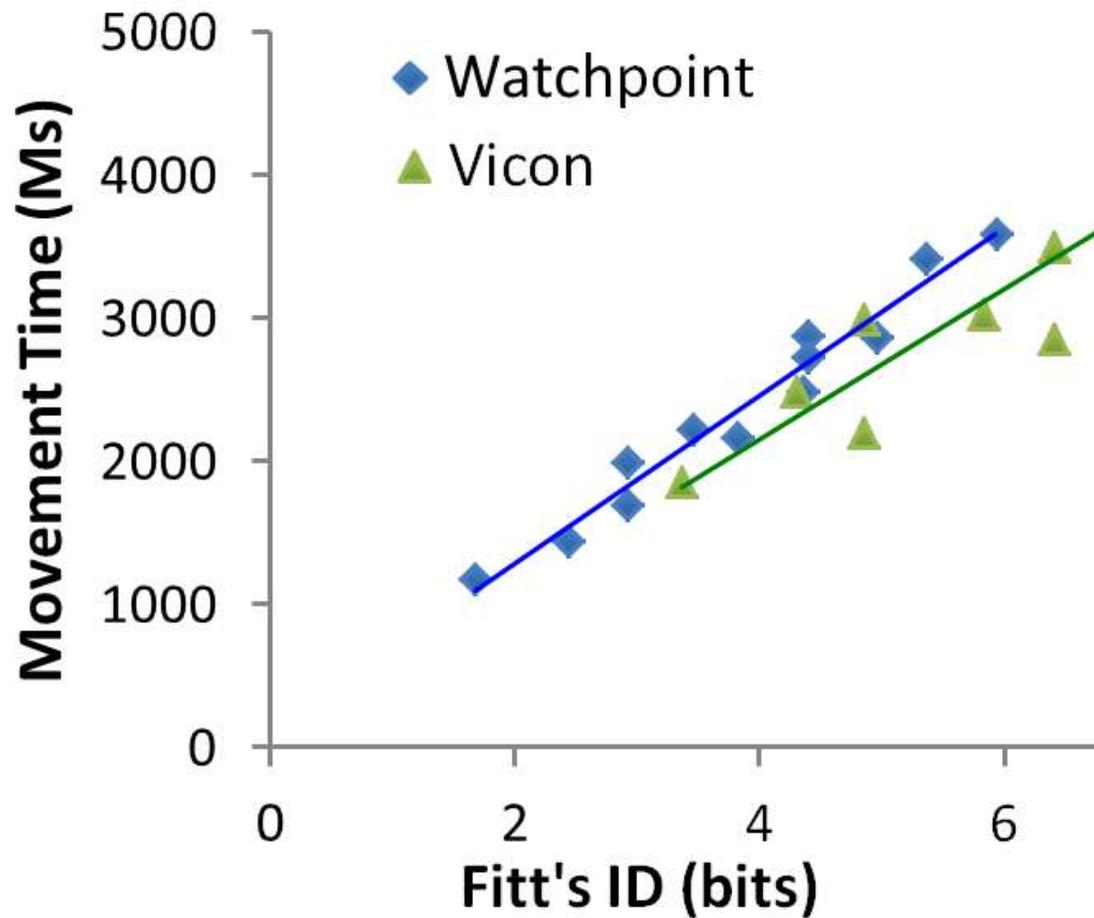
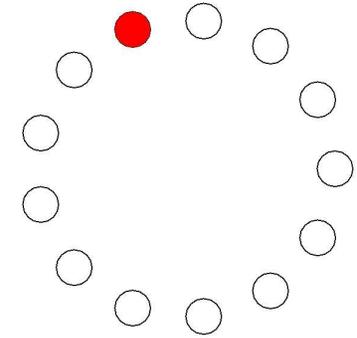
TIIS 2018

# Displays Everywhere

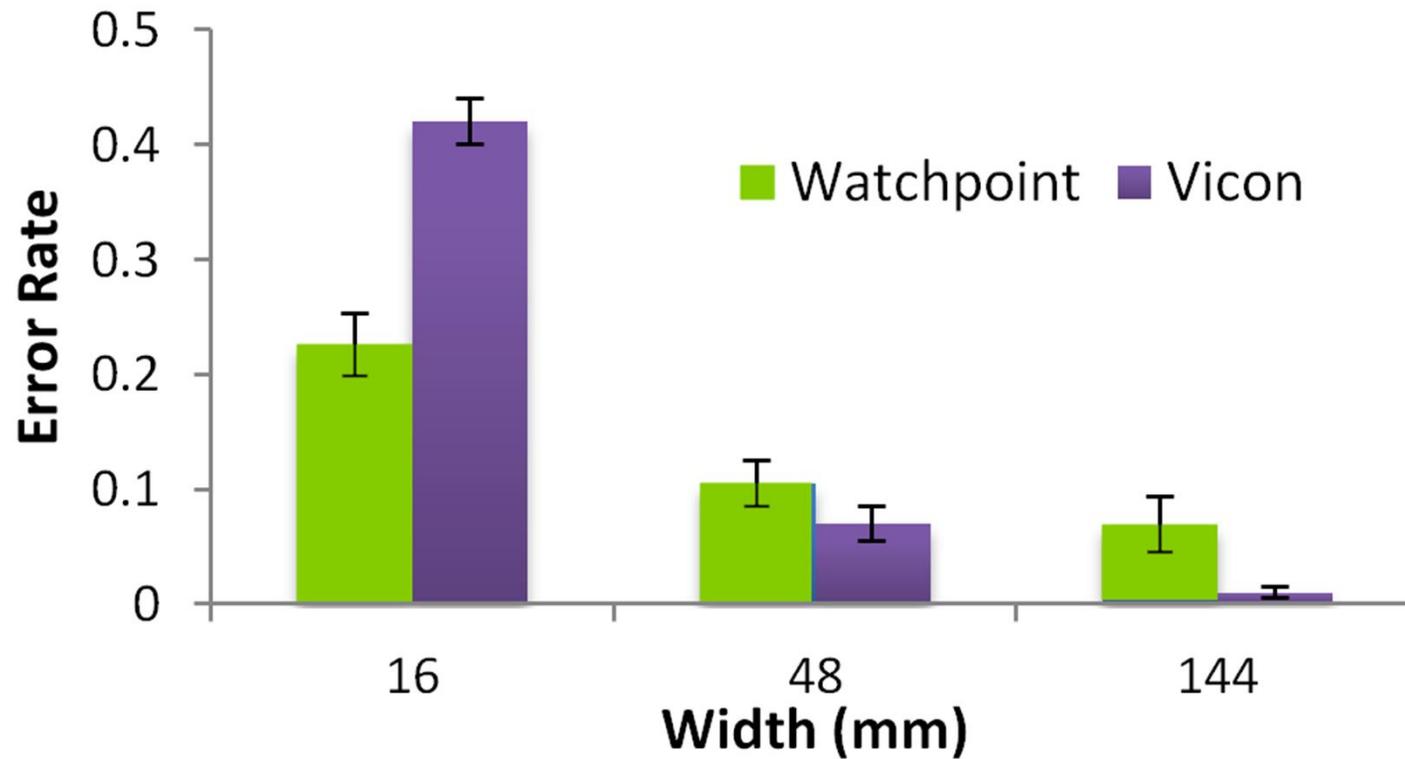




# Evaluation

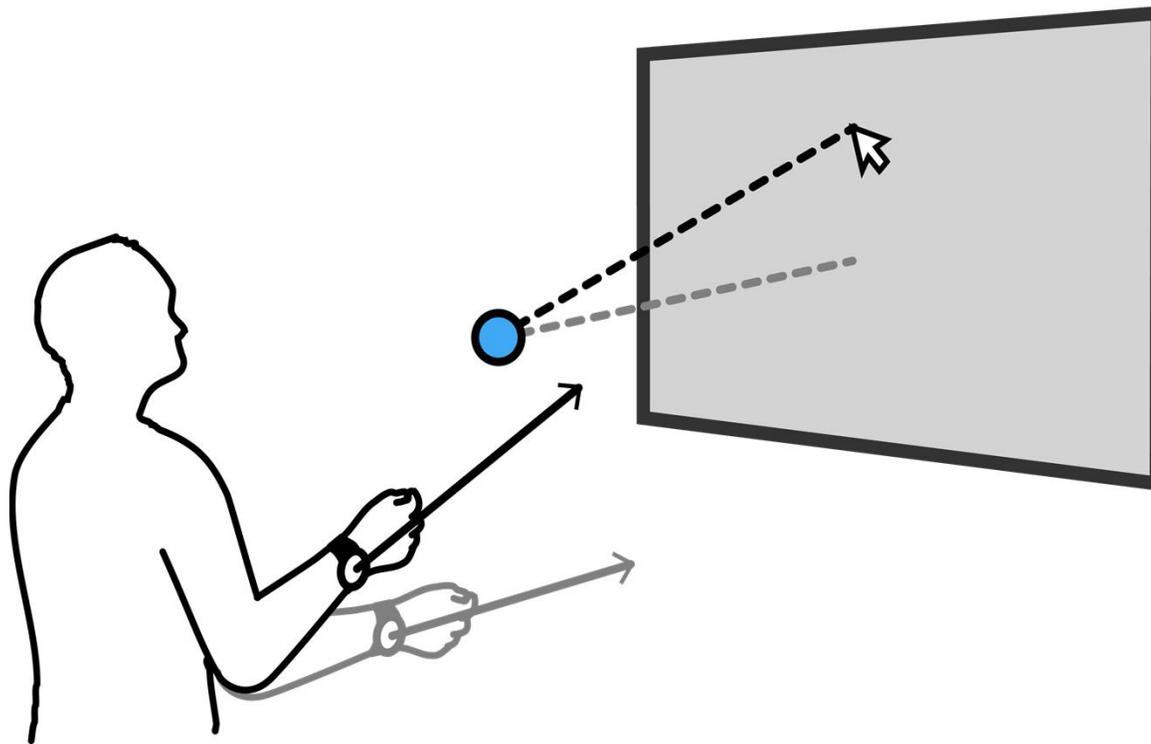


# Evaluation



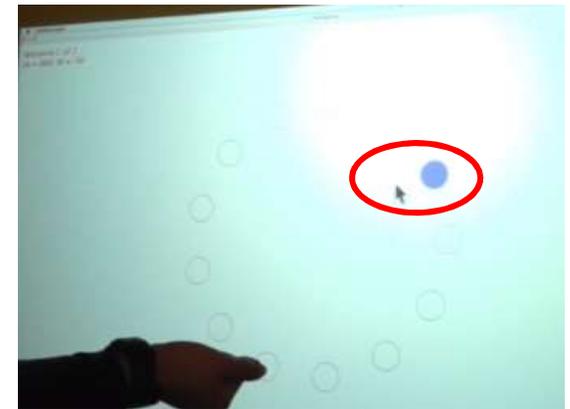
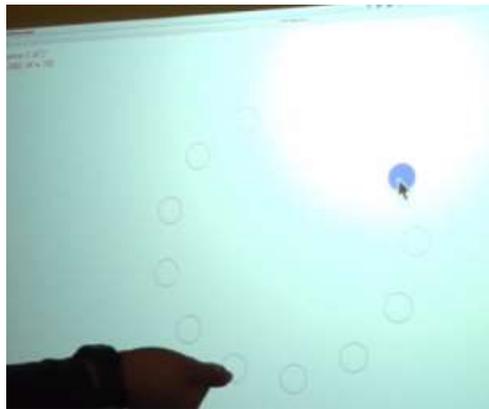
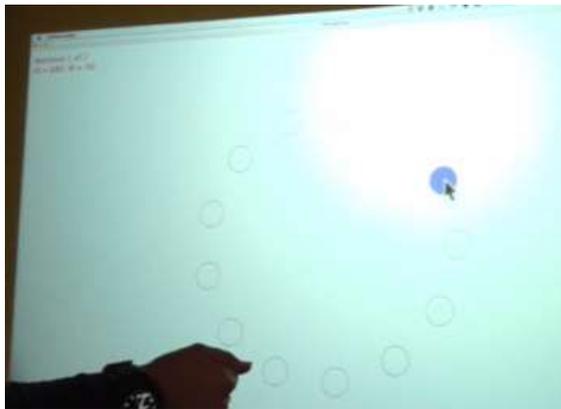
# CD-Gain/Cursor Acceleration

- Trade-off

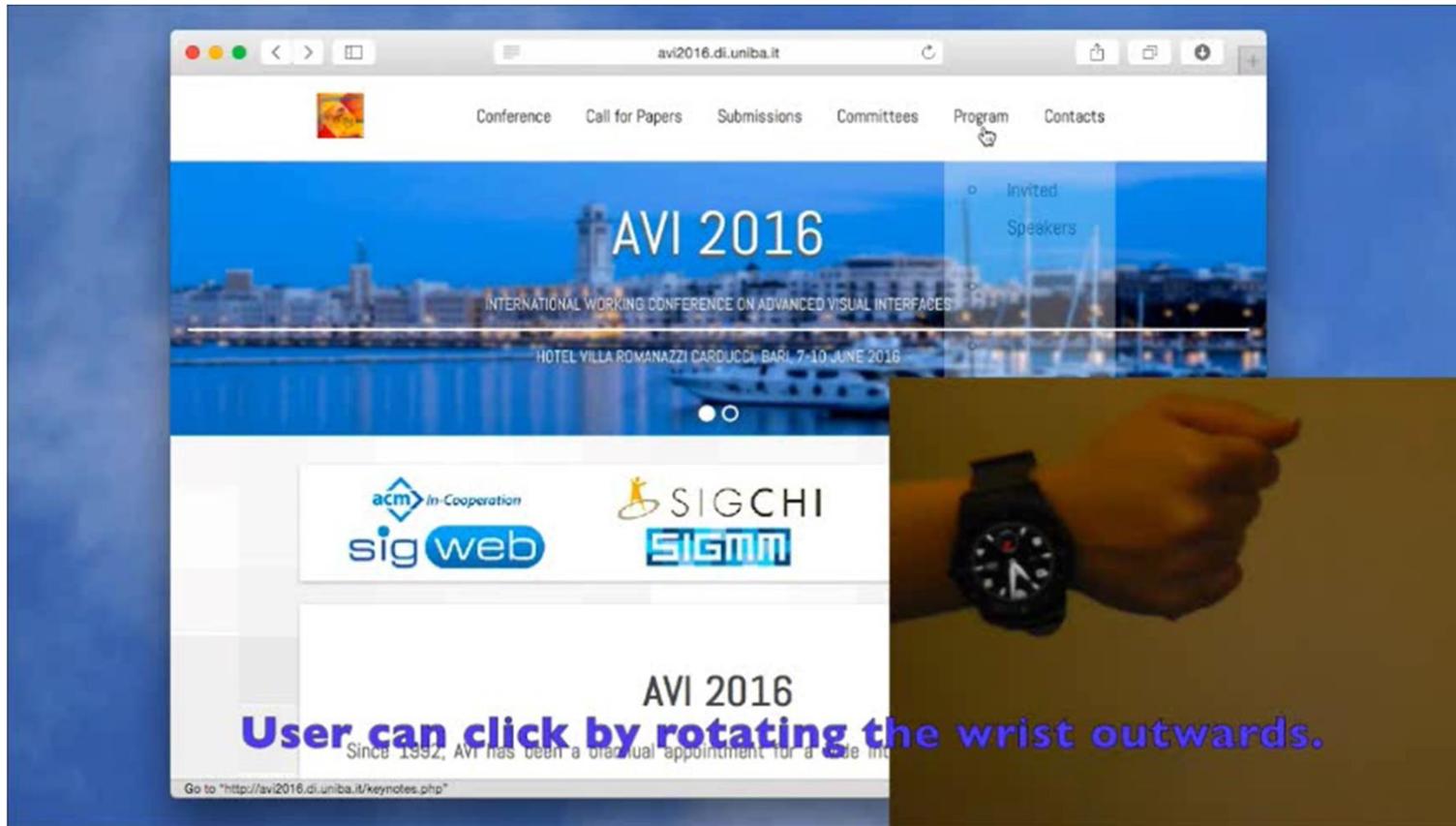


# Stability and Small Targets

- Advantage Watchpoint

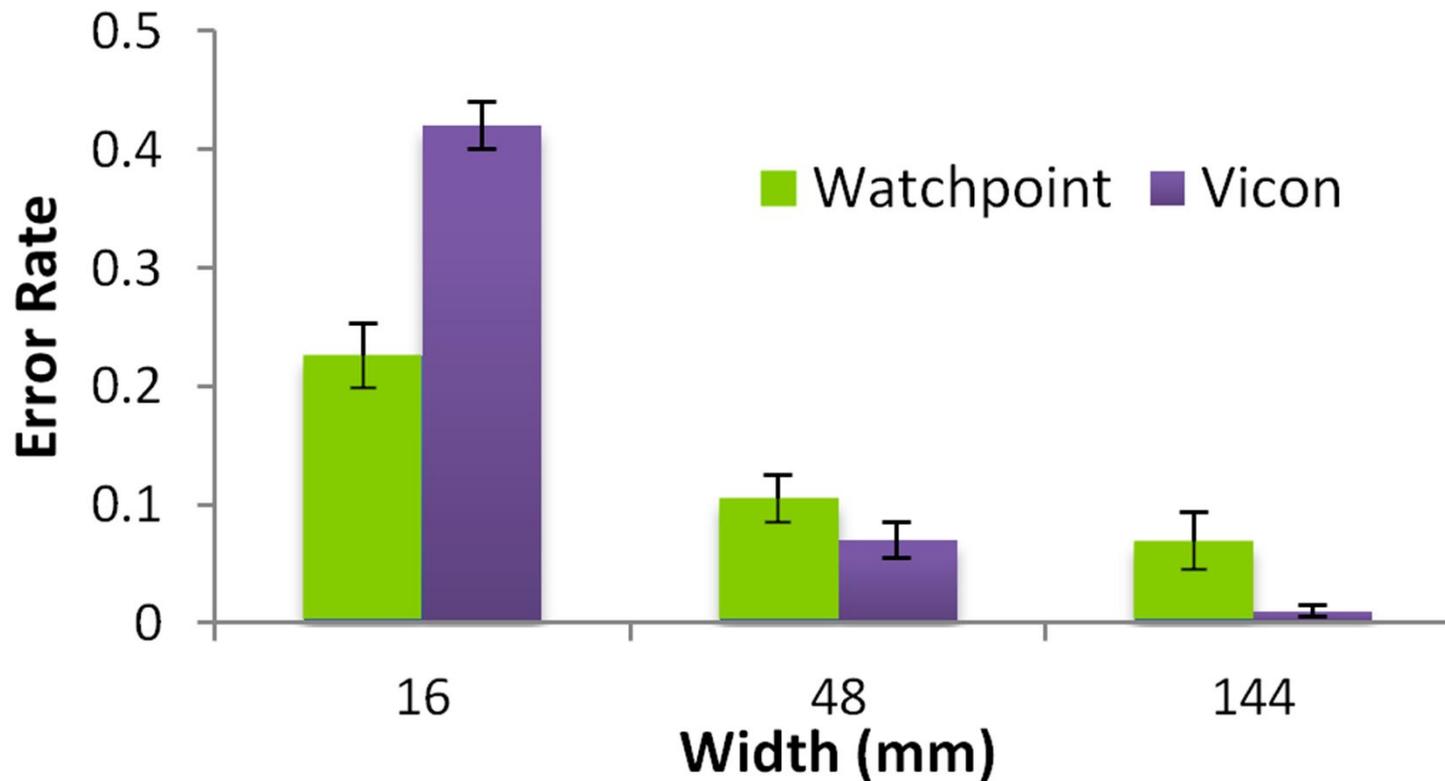


# Stability



# *Beyond Being There*

Hollan and Stornetta

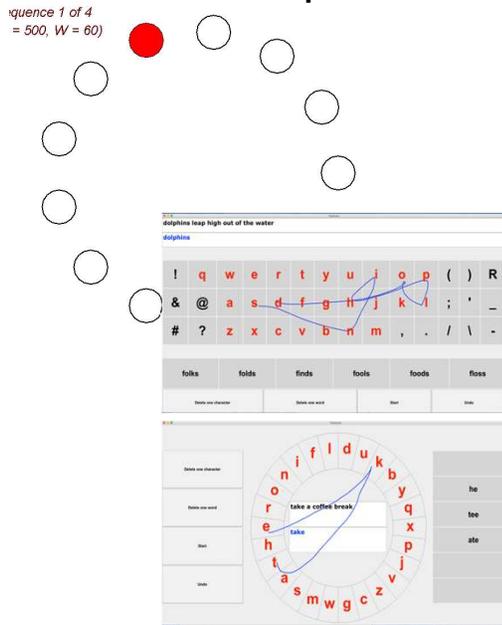


# “Pointing at a Distance with Everyday Smart Devices”

*9am, Thursday,  
Public Large and Shared Displays  
518C, first talk.*

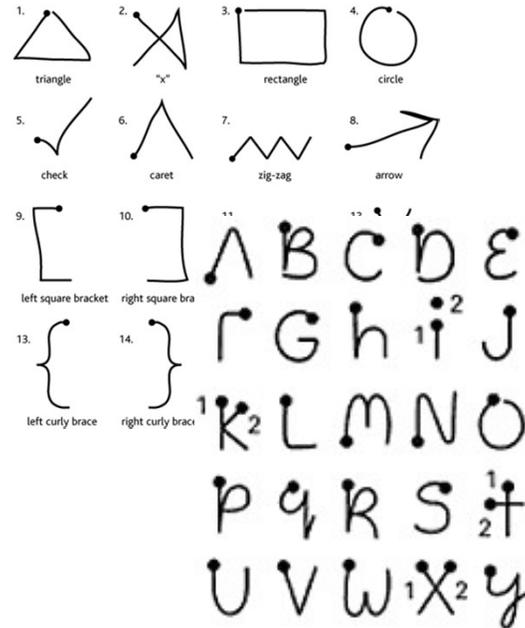
# Wearables for Transient, Subtle, Reliable Interactions

Manipulation and  
Text Input



AVI 2016, CHI 2018

Ideographic Gestures



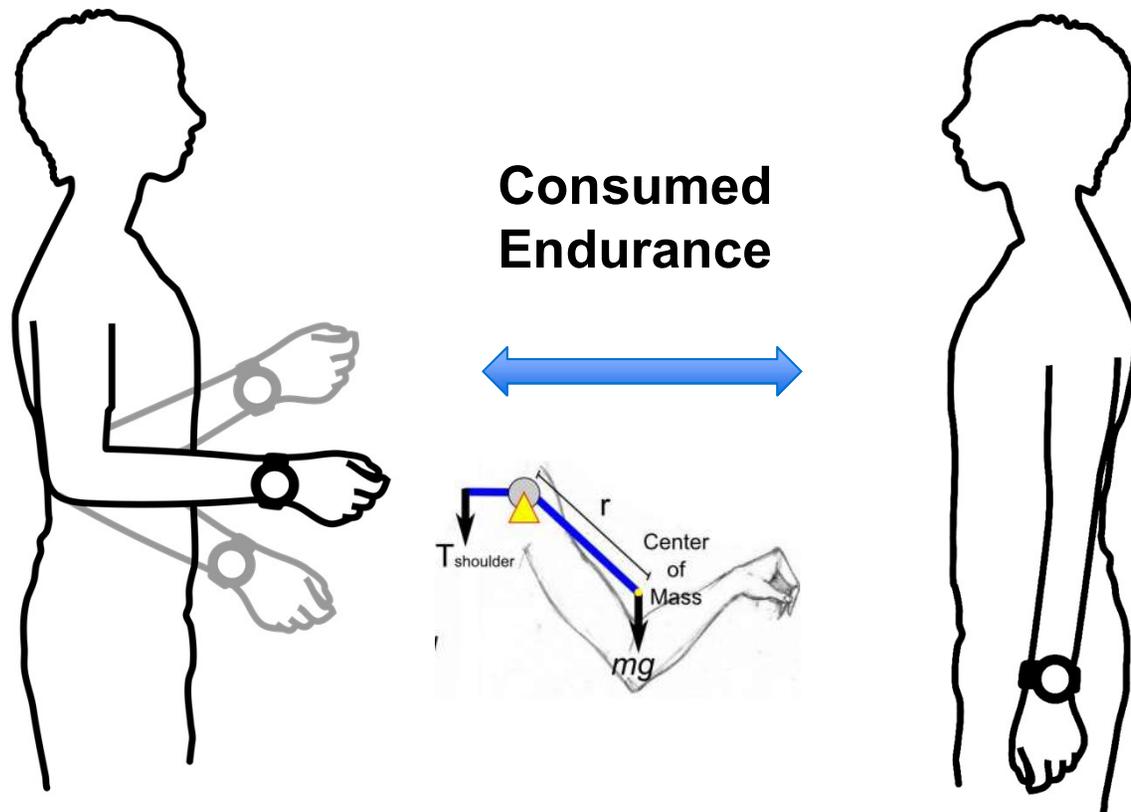
DIS 2017

Finger Gestures

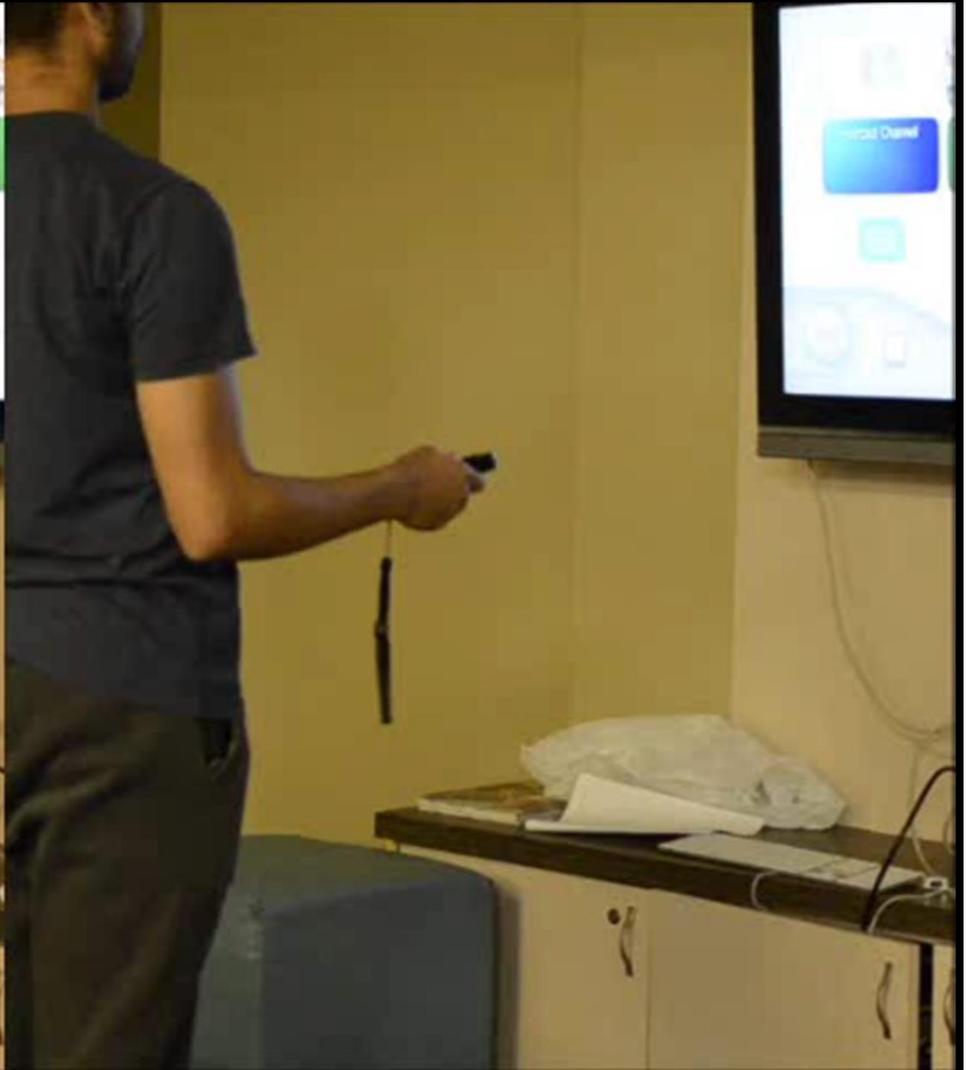
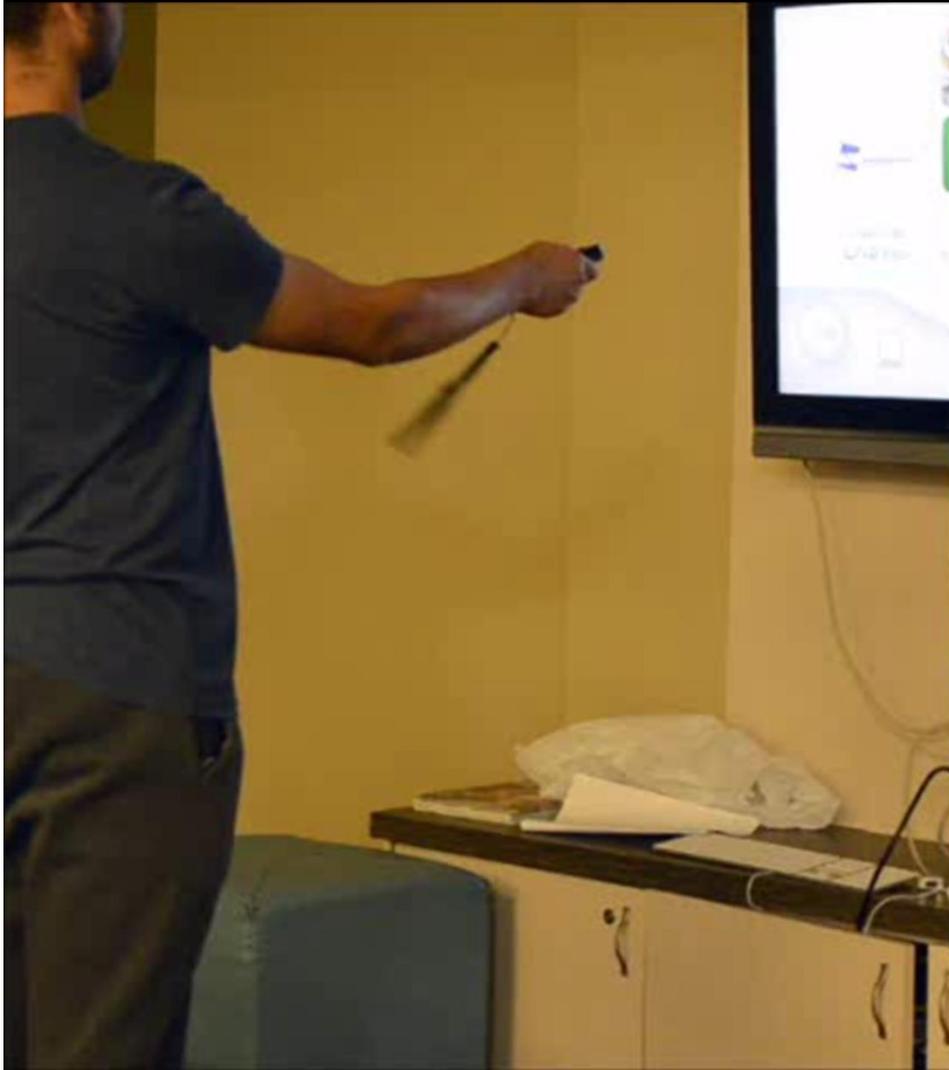


TIIS 2018

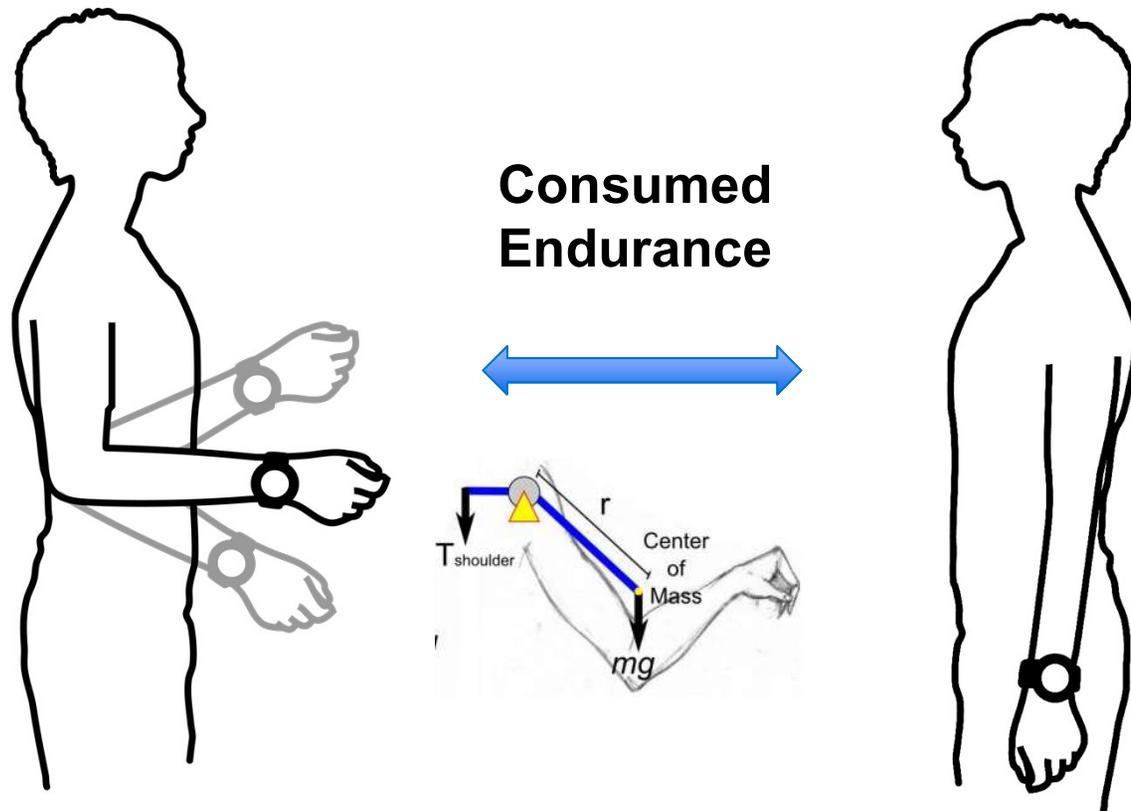
# Gorilla Arm and Gestural Input



Hincapié-Ramos, Guo, Moghadasian, & Irani, Consumed endurance: a metric to quantify arm fatigue of mid-air interactions. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1063-1072). ACM.



# Gorilla Arm and Gestural Input



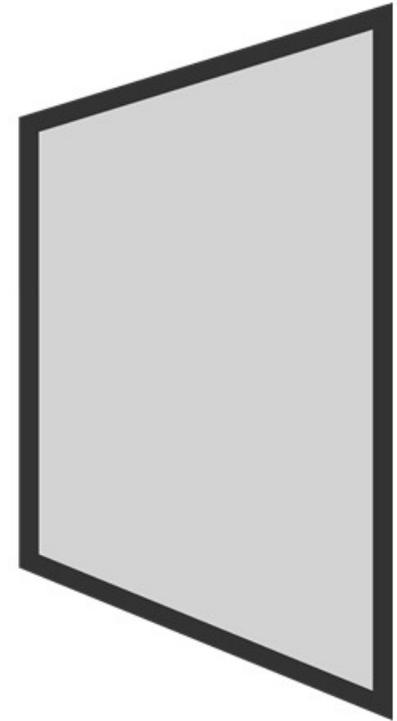
# Side-of-Body, Rich Gesture Input



# Elicitation Study

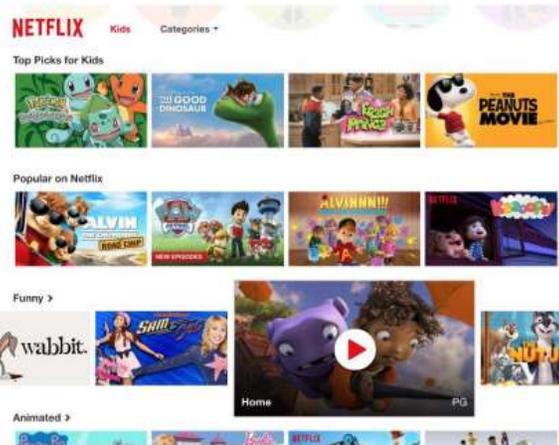
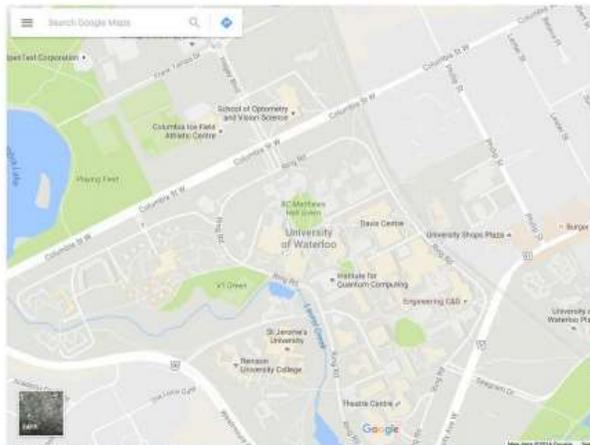


- Given participant a task
  - How would they perform the task?
  - Perform the task
  - Measure characteristics of performance

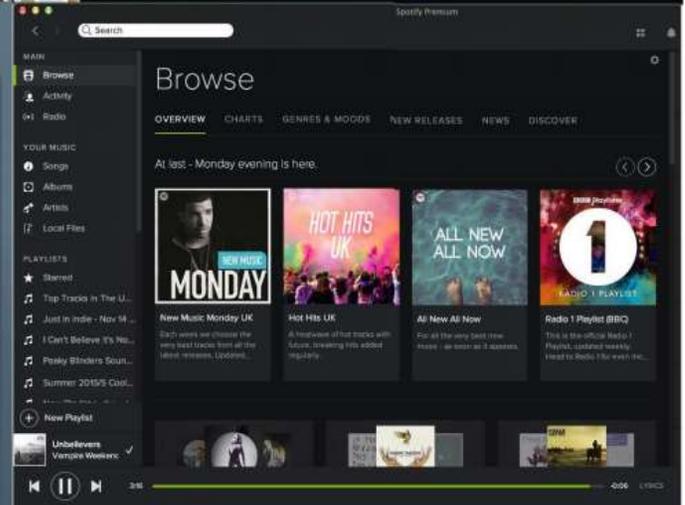


$$AR(r) = \frac{|P|}{|P| - 1} \sum_{P_i \subseteq P} \left( \left| \frac{P_i}{P} \right| \right)^2 - \frac{1}{|P| - 1}$$

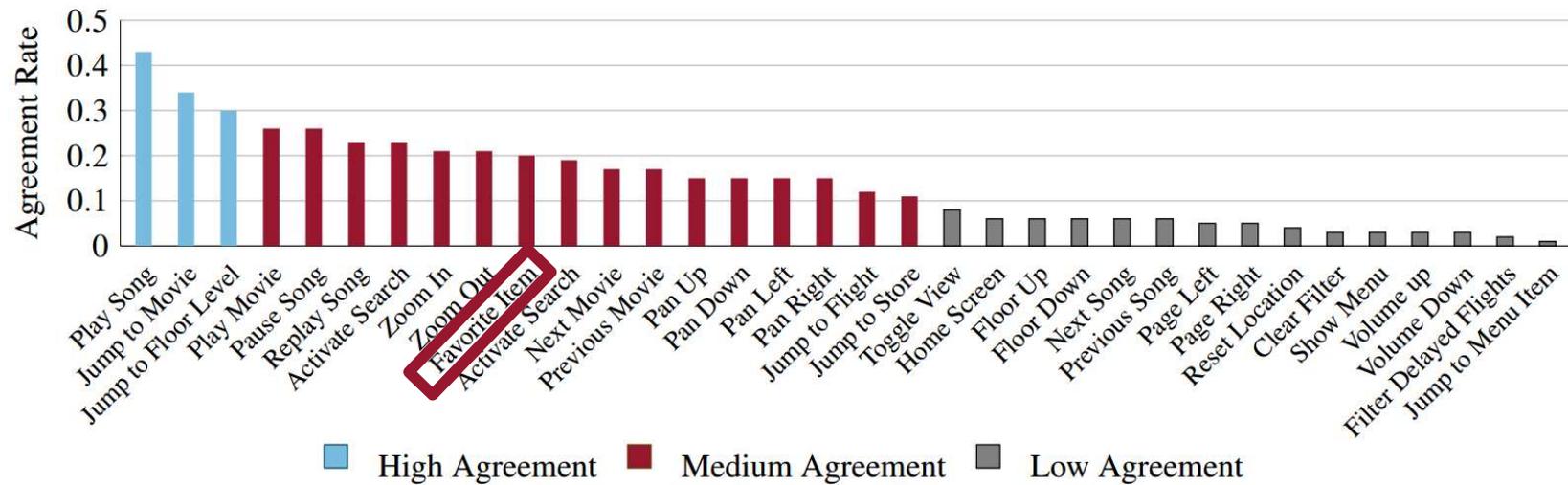
# Tasks



Departures						HYATT PLACE					
Departing To	Airline	Flight	Sched	Gate	Remark	Departing To	Airline	Flight	Sched	Gate	Remark
Akron/Canton, OH	DELTA	1571	9:05p	B6	on time	Augusta, GA	DELTA	1451	7:14p	C41	on time
Akron/Canton, OH	DELTA	1147	5:52p	C46	on time	Austin, TX	DELTA	2471	2:11p	B25	at 2:25p
Akron/Canton, OH	DELTA	1200	3:29p	B28	on time	Austin, TX	DELTA	690	4:10p	A31	at 4:25p
Akron/Canton, OH	Southwest	1194	4:30p	C15	on time	Austin, TX	Southwest	1837	9:46p	B17	on time
Akron/Canton, OH	Southwest	2618	10:00p	C21	on time	Austin, TX	Frontier	223	3:10p	D9	on time
Albany, GA	DELTA	5351	9:10p	D34	on time	Austin, TX	Southwest	2254	8:20p	C1	on time
Albany, NY	DELTA	5047	3:10p	D13	on time	Baltimore/Washington	DELTA	1309	7:10p	A20	on time
Albany, NY	DELTA	1519	7:16p	B9	on time	Baltimore/Washington	Southwest	2413	4:30p	C21	on time
Albany, NY	Southwest	628	4:30p	C20	on time	Baltimore/Washington	DELTA	2024	7:05p	E18	on time
Albuquerque, NM	DELTA	1710	8:15p	E1	on time	Baltimore/Washington	Southwest	719	3:30p	C20	on time
Albuquerque, NM	Southwest	794	3:30p	C5	on time	Baltimore/Washington	DELTA	880	8:35p	B13	on time
Alexandria, LA	DELTA	5156	9:01p	D13	on time	Baltimore/Washington	DELTA	1824	2:58p	A10	on time
Alexandria, LA	DELTA	5156	4:08p	D14	on time	Baltimore/Washington	DELTA	1924	9:55p	A27	on time
Allentown, PA	DELTA	5267	2:27p	D31	at 3:07p	Baltimore/Washington	Southwest	252	5:10p	C4	on time
Allentown, PA	DELTA	2692	8:46p	C34	on time	Baltimore/Washington	Southwest	468	4:35p	C9	at 4:50p
Amsterdam	DELTA	072	8:34p	F6	on time	Baltimore/Washington	Southwest	1525	4:21p	B6	at 4:30p
Amsterdam	Southwest	622	11:40p	on time	Baltimore/Washington	Southwest	730	8:35p	C20	on time	
Amsterdam	DELTA	074	9:06p	E10	on time	Baton Rouge, LA	DELTA	5247	9:49p	D31	on time
Appleton, WI	DELTA	5323	3:01p	D14	at 3:10p	Baton Rouge, LA	DELTA	5137	6:55p	D15	on time
Appleton, WI	DELTA	2962	7:25p	C43	on time	Baton Rouge, LA	DELTA	5440	4:21p	D32	on time
Asheville, NC	DELTA	5189	4:44p	C30	on time	Baton Rouge, LA	DELTA	5081	8:50p	D14	on time
Asheville, NC	DELTA	5584	3:00p	C55	on time	Baton Rouge, LA	DELTA	5051	5:56p	C52	on time
Asheville, NC	DELTA	5252	10:50p	D16	on time	Bentonville, AR	DELTA	5149	4:50p	D15	on time
Asheville, NC	DELTA	2289	8:36p	B3	on time	Bentonville, AR	DELTA	5265	3:14p	D33	at 3:19p
Augusta, GA	DELTA	670	9:15p	B28	on time	Bentonville, AR	DELTA	2119	9:15p	B1	on time
Augusta, GA	DELTA	5107	5:30p	D46	on time	Birmingham, AL	DELTA	2383	7:55p	B10	on time
						Birmingham, AL	DELTA	117	5:57p	E34	on time
						Birmingham, AL	DELTA	1063	11:05p	B31	on time
						Bloomington, IL	DELTA	5056	9:08p	D44	on time
						Bloomington, IL	DELTA	5460	2:54p	C35	on time
						Bogota, Colombia	DELTA	981	5:47p	E6	on time
						Boston, MA	DELTA	1800	4:29p	C49	on time
						Boston, MA	DELTA	903	8:35p	A9	on time
						Boston, MA	DELTA	2100	7:15p	B18	on time
						Boston, MA	DELTA	1900	5:45p	A26	on time
						Boston, MA	DELTA	2300	9:49p	B22	on time
						Boston, MA	Southwest	468	4:35p	C5	at 4:50p
						Boston, MA	Southwest	960	2:50p	A19	on time
						Bradley	Southwest	778	8:25p	C2	on time
						Bradley	DELTA	514	6:15p	B16	on time
						Bradley	DELTA	1062	9:45p	B3	on time
						Bradley	DELTA	1724	3:14p	B6	on time
						Braesla	DELTA	221	9:29p	E14	on time
						Bristol, TN	DELTA	5476	9:45p	D35	on time
						Bristol, TN	DELTA	5151	4:59p	D13	on time
						Brunswick, GA	DELTA	1098	7:05p	C50	on time
						Brunswick, GA	DELTA	5529	7:59p	D30	on time
						Brunswick, GA	DELTA	5527	2:54p	D28	on time
						Brussels	DELTA	080	5:36p	F2	on time
						Buenos Aires	DELTA	101	7:36p	E8	on time
						Buffalo, NY	DELTA	2473	8:44p	B18	on time
						Buffalo, NY	DELTA	1176	4:10p	B2	on time
						Burlington, VT	DELTA	5025	7:04p	D46	on time



# Agreement

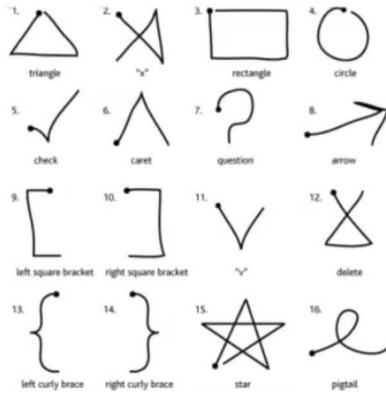


## Favorite Item

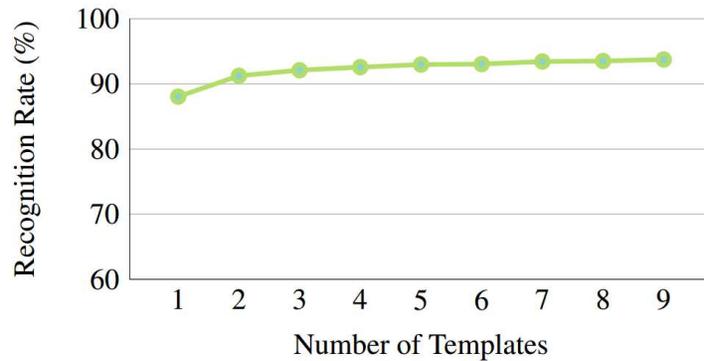


ELICITED GESTURES FOR "FAVORITE ITEM"

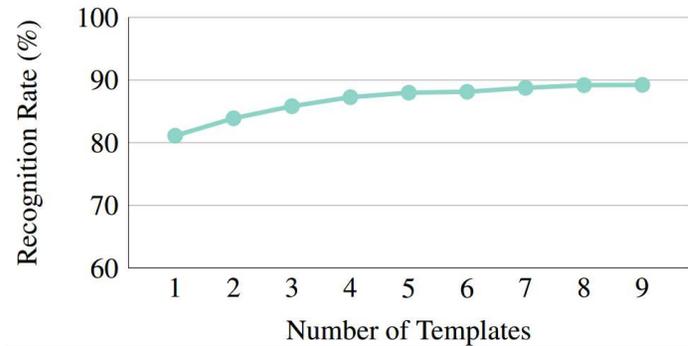
# Ideographic & Alphanumeric



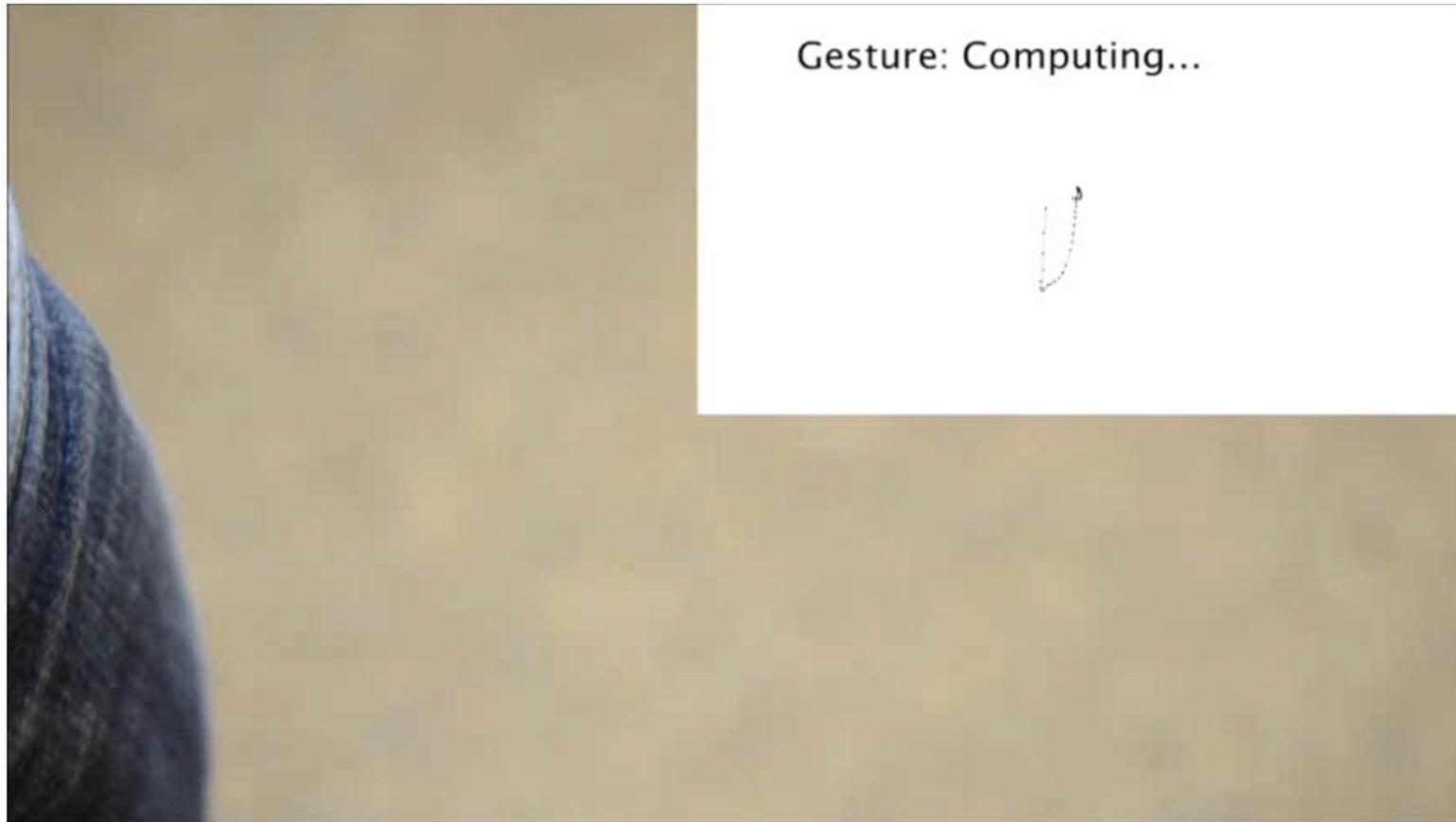
\$1 Gesture Set



Palm Graffiti

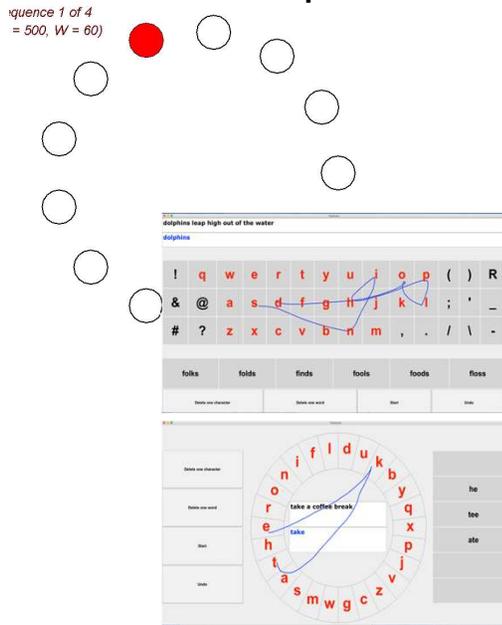


# Side-of-Body, Rich Gesture Input



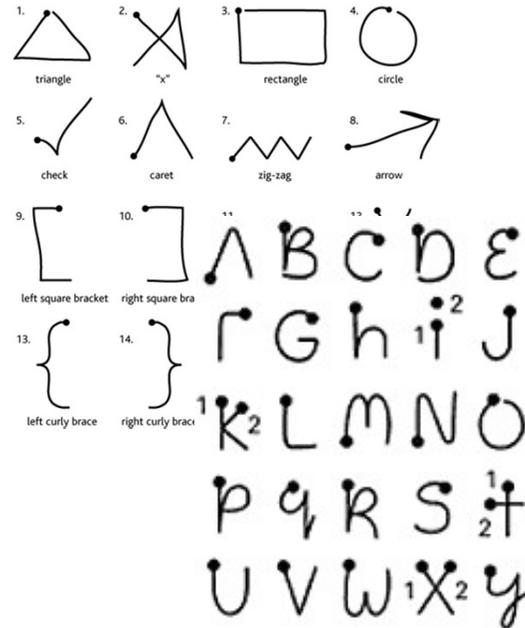
# Wearables for Transient, Subtle, Reliable Interactions

Manipulation and  
Text Input



AVI 2016, CHI 2018

Ideographic Gestures



DIS 2017

Finger Gestures

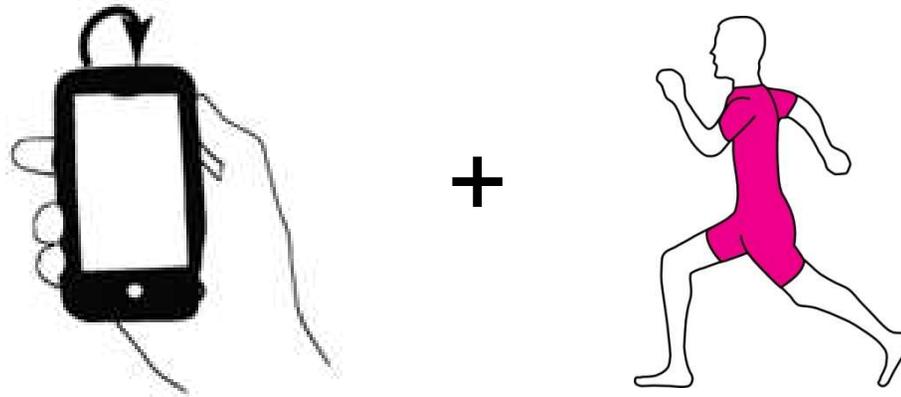


TIIS 2018

# Recognition Challenge

Gestures tend to be **simple**  
**discrete** gestures involving **one**  
**(maybe two) axis** with **low**  
kinematic impulse

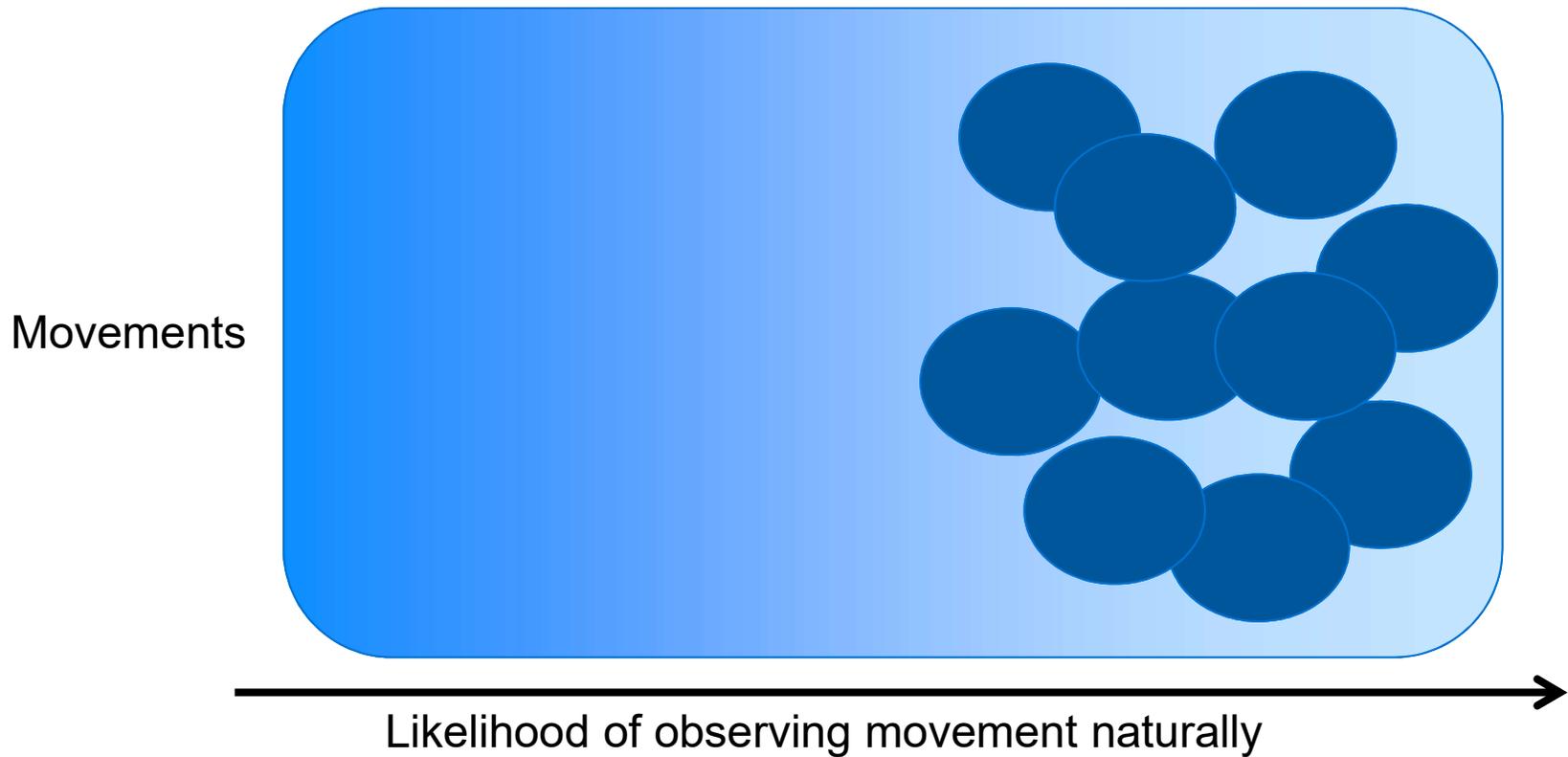
Ruiz, Li, and Lank, CHI 2011



# Solutions for Reliable Input?

- **Better gestures**
  - But limited in number ...
- **Delimiters**
  - Like a mode switch
- **Recognition strategies**
  - Tighter thresholding

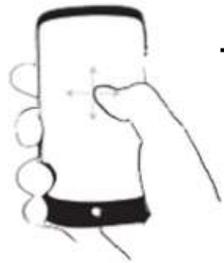
# Challenge => Tighter Thresholding



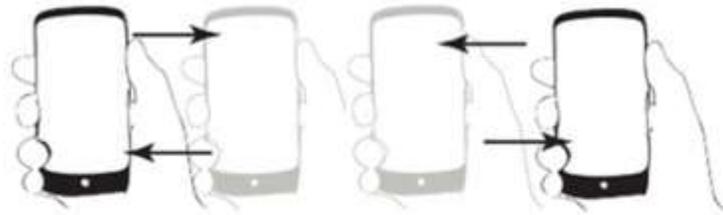
*How can we preserve both  
**high recall and high precision** when  
gestures collide with everyday motion?*

# Conceptualization: Eyes-Free Interaction

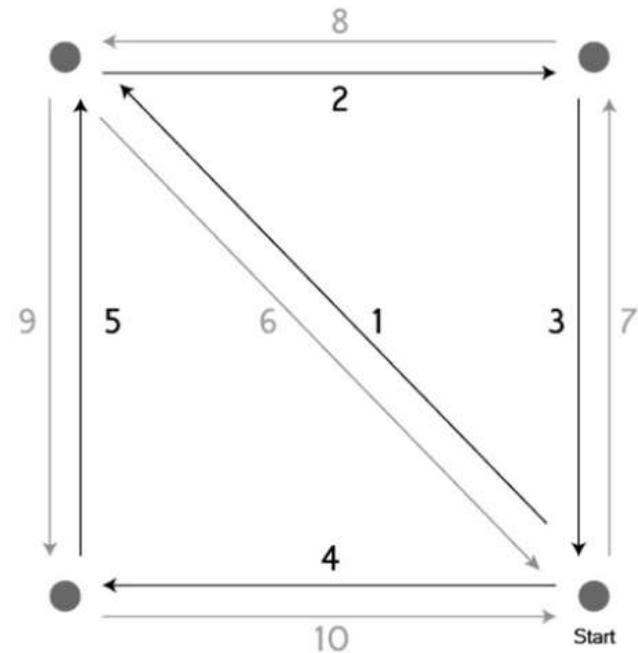
“Tap, Swipe, Move” by Negulescu, Ruiz, Li and Lank, AVI 2012



Tap or Swipe



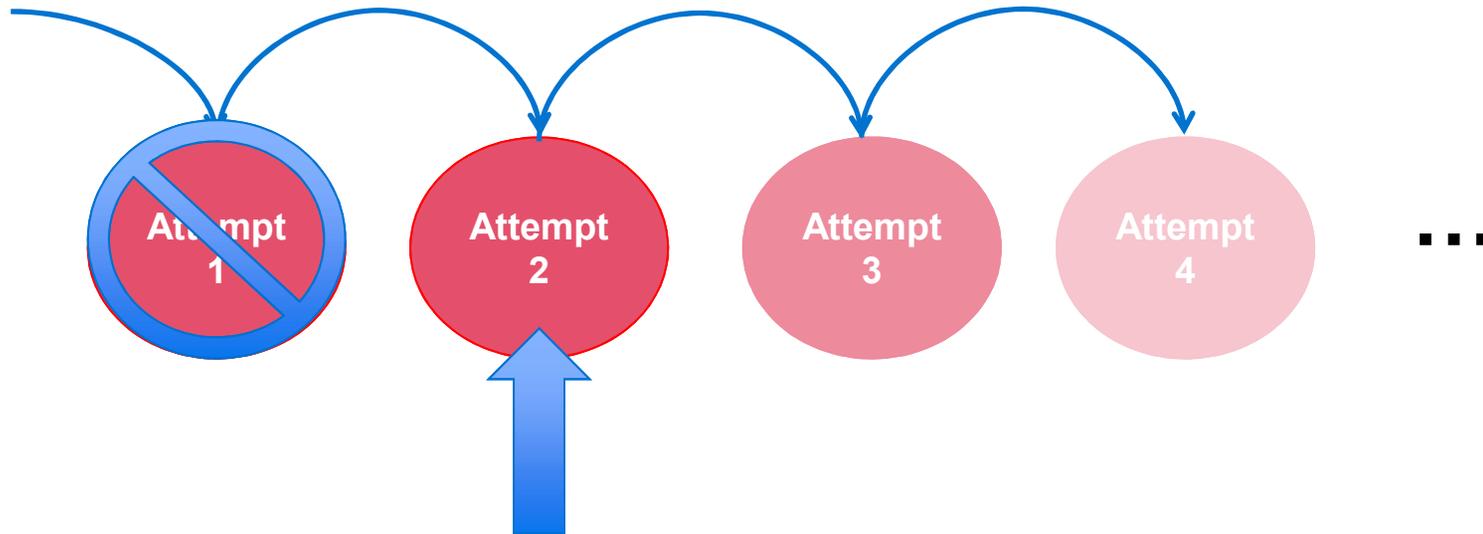
Motion gestures



# Take-Aways

- Main take-away:
  - Even when touch/swipe designed for eyes-free, gestural input still better.
- Additional observation:
  - Effect of recognition errors
  - In particular, single error appears to have ~0 cost!
    - User just repeats gesture.

# Cost of Errors



***Reliability vs Perceived Reliability***

# Bi-Level Thresholding

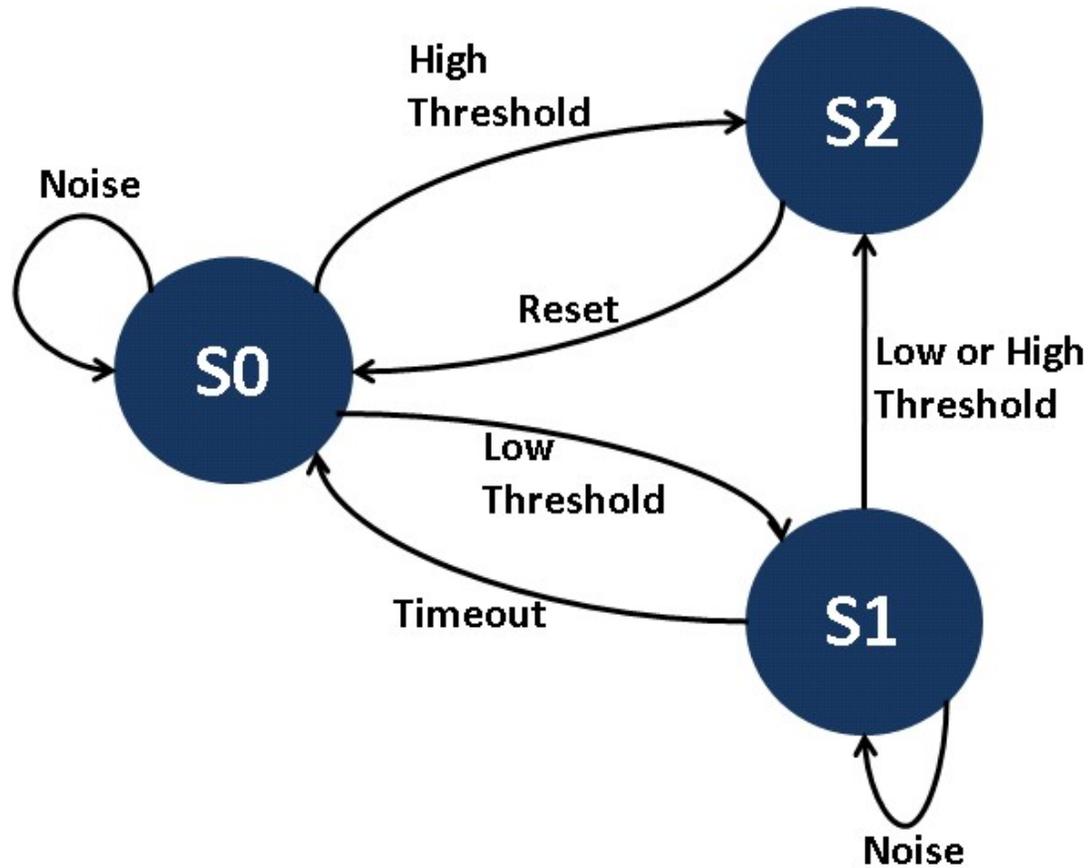
Observation:

On false negative, user repeats gesture

## Safety Net

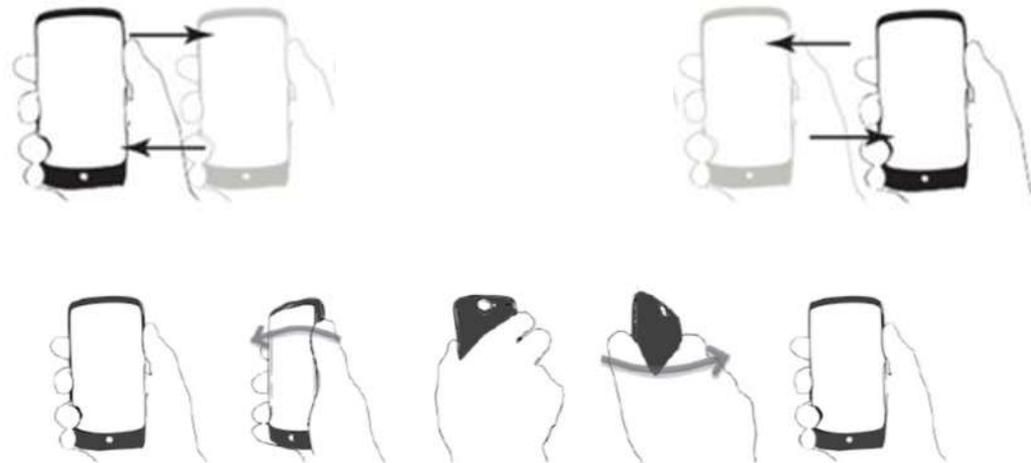
- Observing two possible gestures = observing one highly probable gesture
- One tightly thresholded initial model
- One loosely thresholded double model

# Bi-level Thresholding Recognition



# Preliminary Study

- Built a simple double-threshold recognizer
  - 3 gestures – flick left, flick right, double-flip



- Constructed HMM-based recognizer

# Preliminary Study

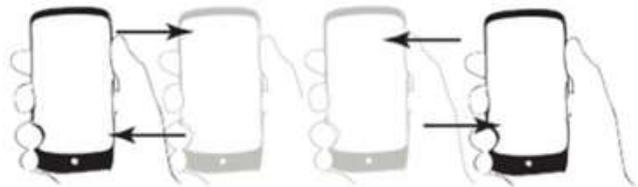
- Bi-level threshold recognizer achieved 93% recall with 95.3% precision for 2 attempts
- 65% of gestures captured with double threshold
  - Vs 35% with single threshold (26% first attempt + 9% second attempt)

# Evaluating Bi-Level Thresholding

- Reliability or perceived reliability ...
  - Is it higher recognition or recognition strategy?
- Bi-level behavior ...
  - How does bi-level thresholding perform on larger gesture sets?

# User Reaction

- 5-gesture walking experiment



# *Just Noticeable Difference* Experiment

- *Wizard-of-Oz Recognizer*
  - Controlled recognition rates of 50%, 60%, 70% for single threshold
  - Ensured *identical recognition rates* for bi-level thresholding

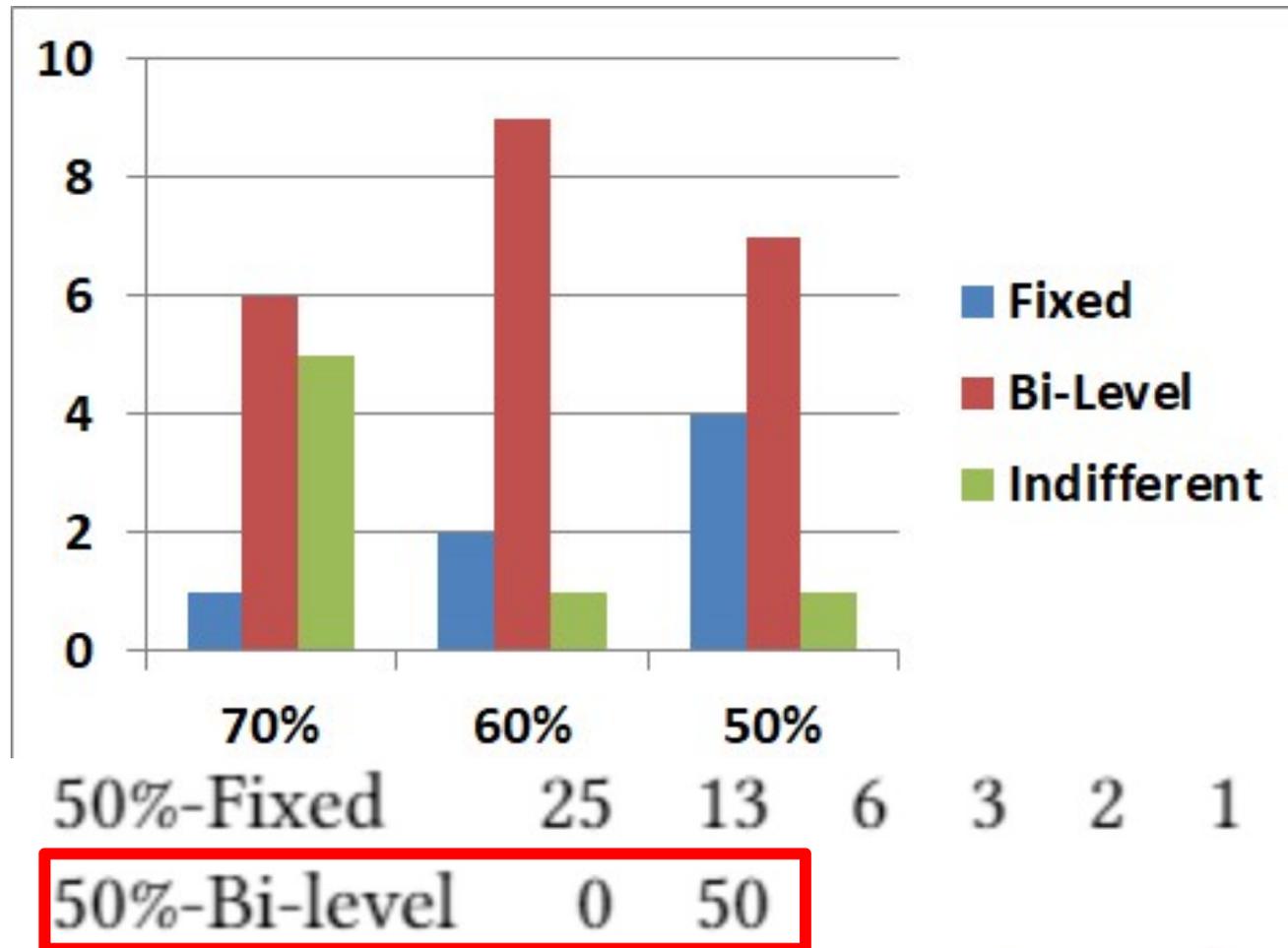
# Experimental Design (2)

	Required attempts						total attempt
	1	2	3	4	5	6	
70%-Fixed	35	11	3	1			70
70%-Bi-level	30	20					70
60%-Fixed	30	12	5	2	1		82
60%-Bi-level	18	32					82
50%-Fixed	25	13	6	3	2	1	97
50%-Bi-level	0	50					100

# Results: TLX

	Fixed	Bi-level	F	p
WWL	34.3	29.2	4.478	<.05
Mental Demand	25.1	25.2	0.003	.96
Physical Demand	31.1	29.5	0.267	.609
Temporal Demand	31.7	28.3	1.371	.250
Performance	28.9	19.2	8.352	<.01
Effort	33.0	28.0	2.198	.148
Frustration	32.8	29.1	1.304	.261

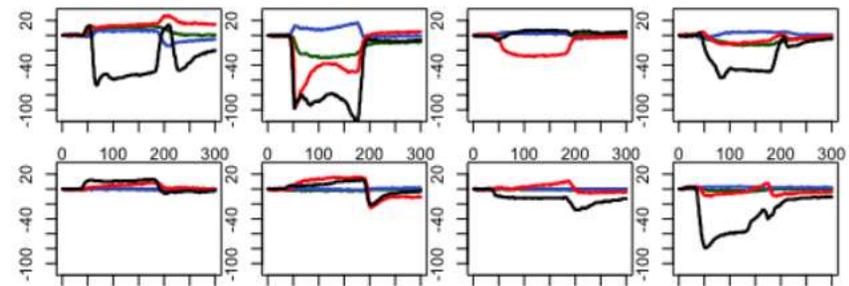
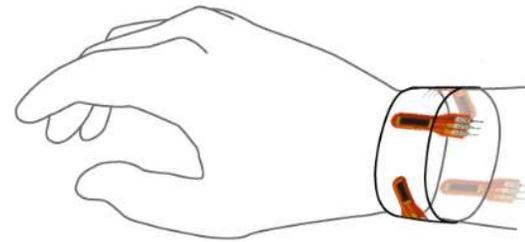
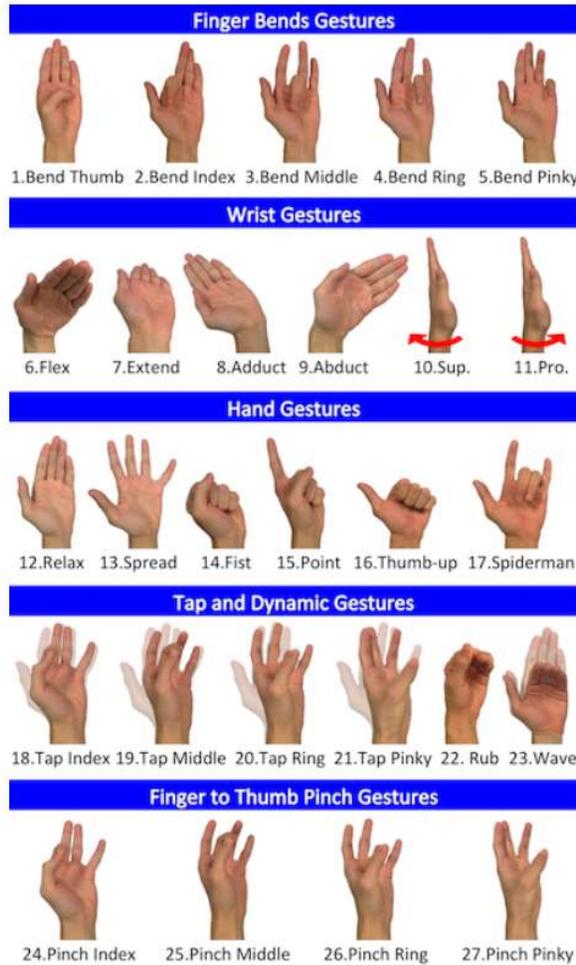
# Results: User Preference



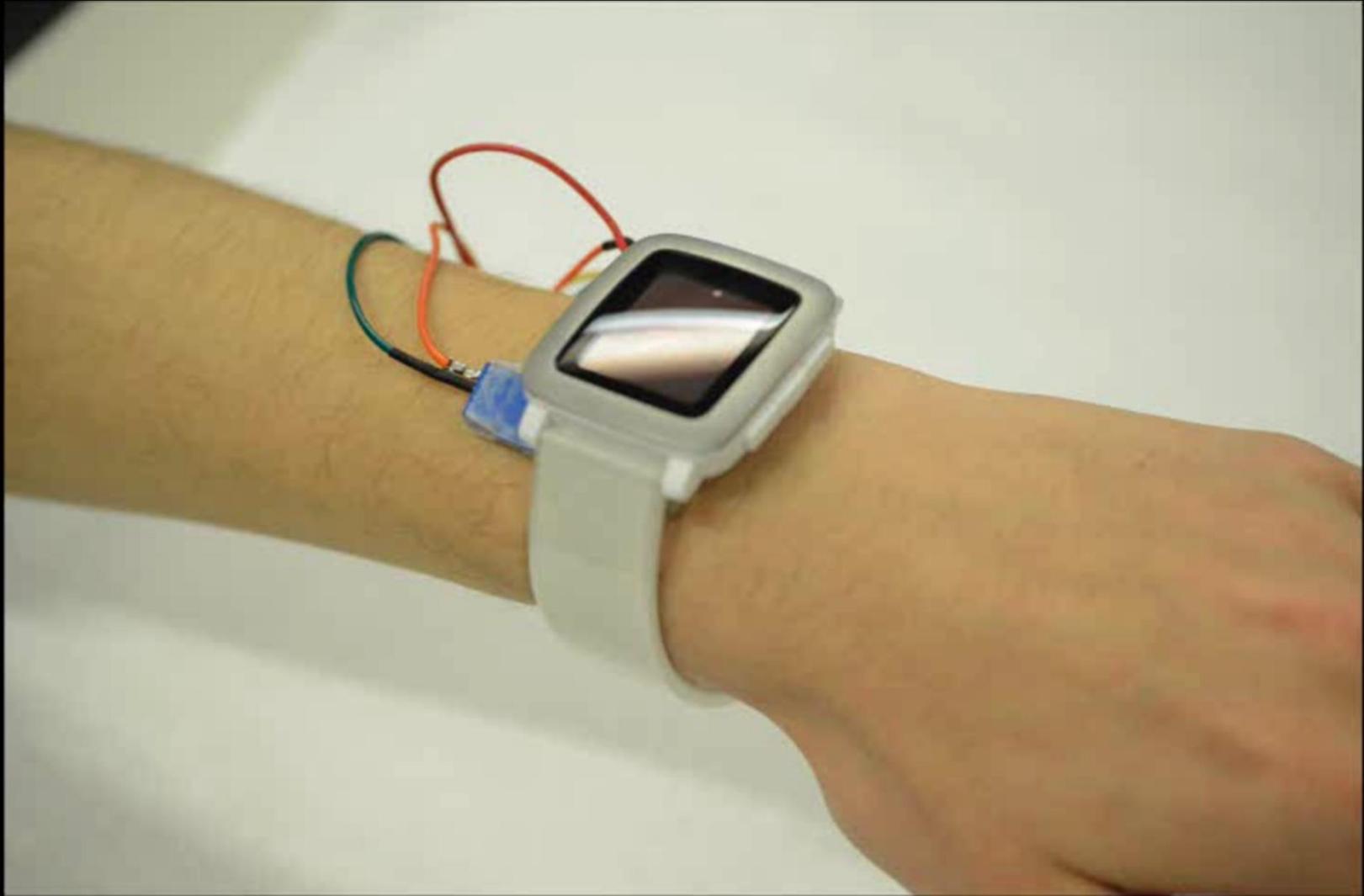
# Same Work, Varied Preference

	Required attempts						total attempt
	1	2	3	4	5	6	
70%-Fixed	35	11	3	1			70
70%-Bi-level	30	20					70
60%-Fixed	30	12	5	2	1		82
60%-Bi-level	18	32					82
50%-Fixed	25	13	6	3	2	1	97
50%-Bi-level	0	50					100

# Behavior: Hand Gestures



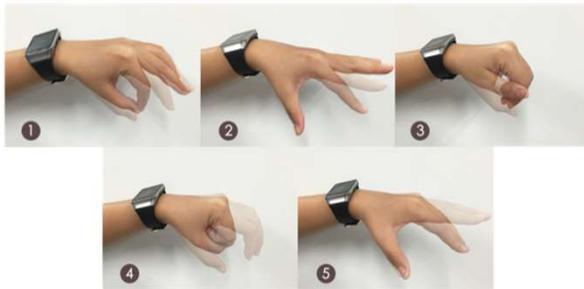
# Subtle Hand/Finger Gestures



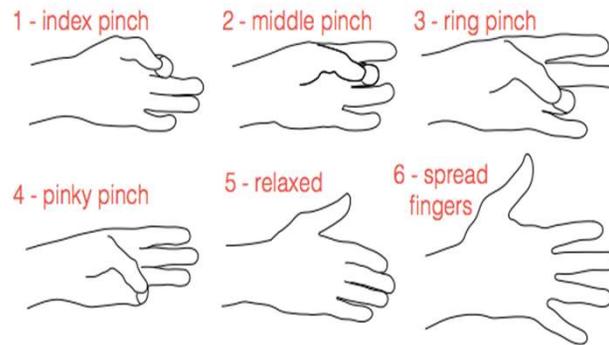
# Gesture Set

Empress, CHI 2016

Serendipity, CHI2016



WristFlex, UIST 2014



**Finger gestures:**

Thumb Index Middle Ring Pinky

**Wrist gestures:**

Flex Extend Adduct Abduct Sup. Pro.

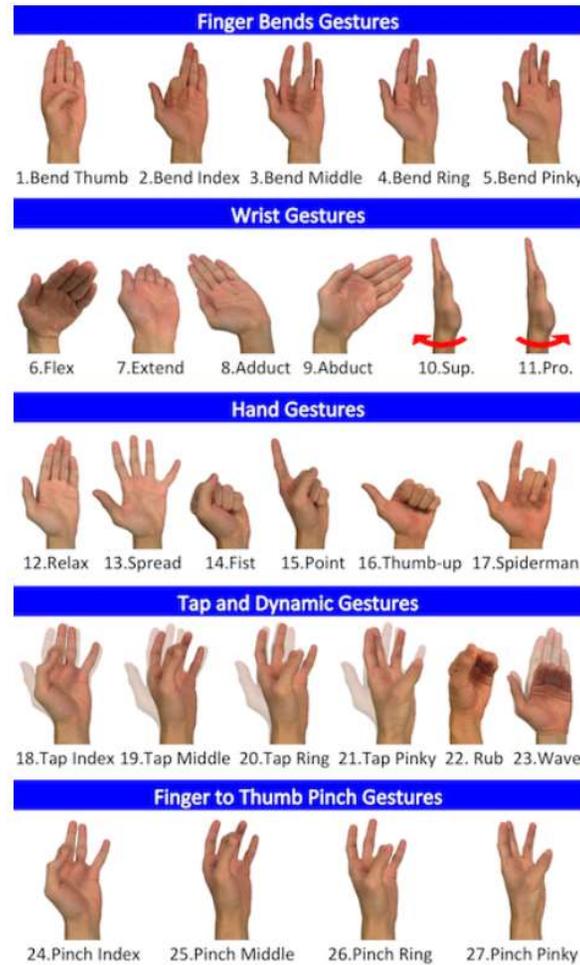
**Other:**

Palm Spread Fist Point

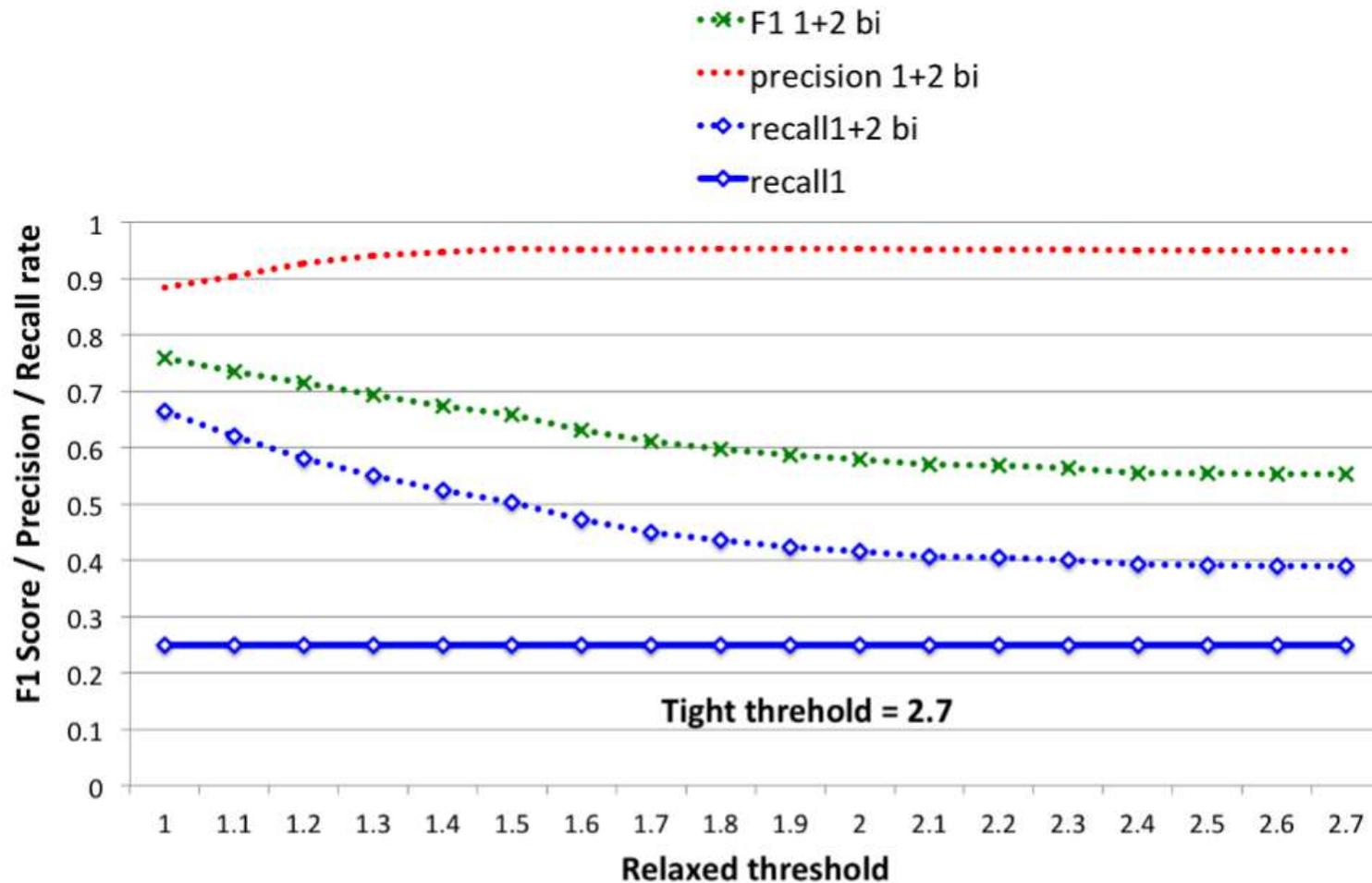
Tomo, UIST2016



# Gesture Set

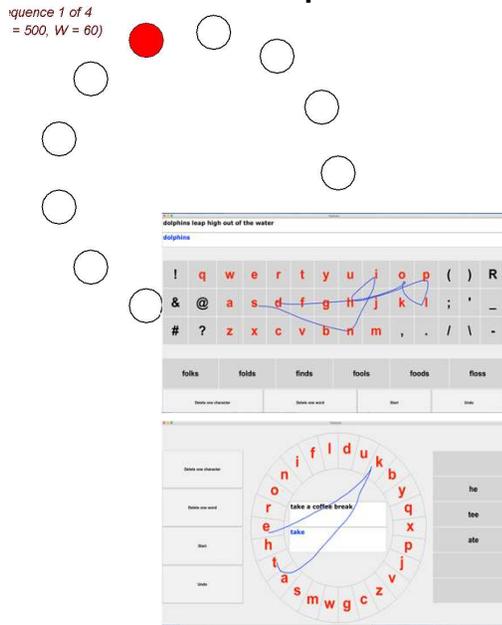


# Bi-Level Behavior



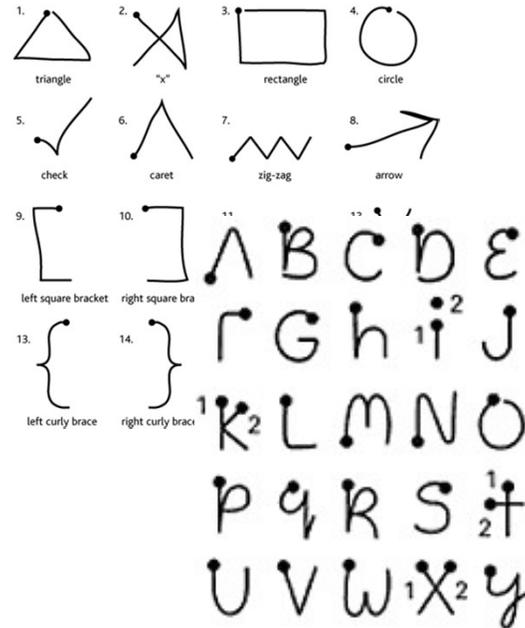
# Wearables for Transient, Subtle, Reliable Interactions

Manipulation and  
Text Input



AVI 2016, CHI 2018

Ideographic Gestures



DIS 2017

Finger Gestures



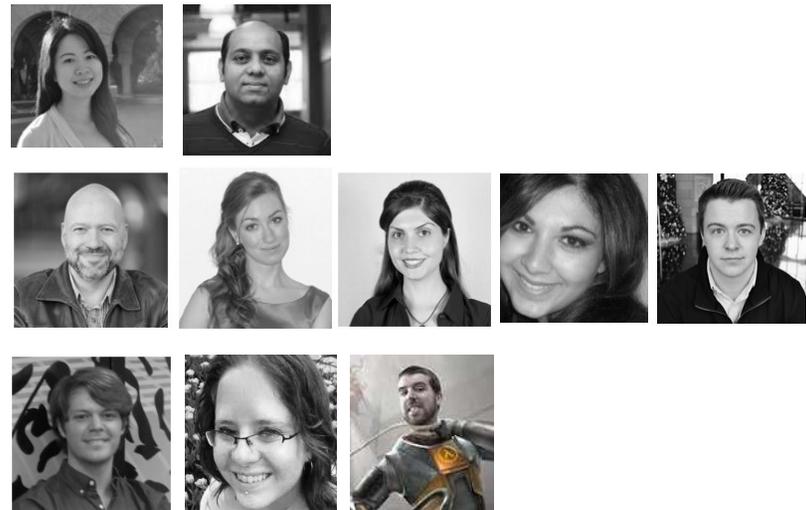
TIIS 2018

# Colleagues + Students/Post-Docs

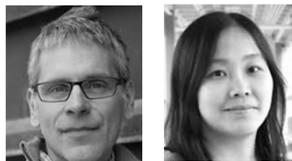
## LOKI



## Grad Students and Post-Docs



## Waterloo



# Wearables for Rich Subtle Transient Interactions

Yang Li, Sylvain Malacria, Mathieu Nancel, Keiko Katsuragawa, Dan Vogel, Jim Wallace, Krzysztof Pietroszek, Shaishav Siddhpuria, Edmund Liu, Jaime Ruiz, Ankit Kamal, Alec Azad, Matei Negulescu, Jane Henderson.

## Questions?

