Evaluating User Preferences on Interaction for Single User Cross Reality Transition of 3D Virtual Objects

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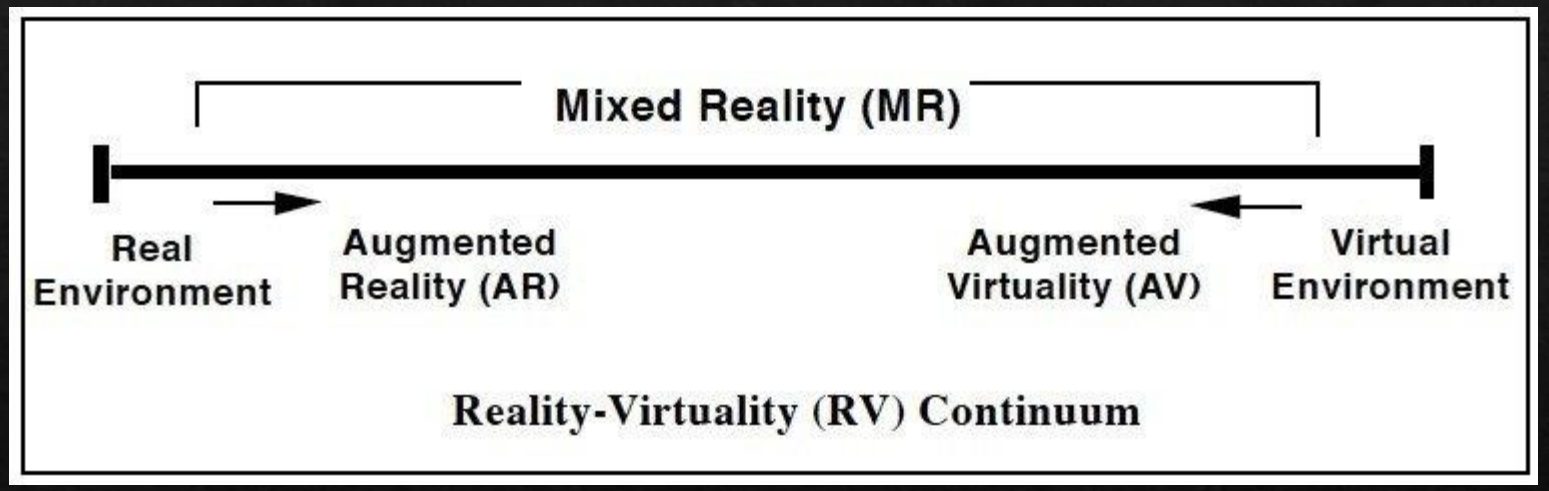
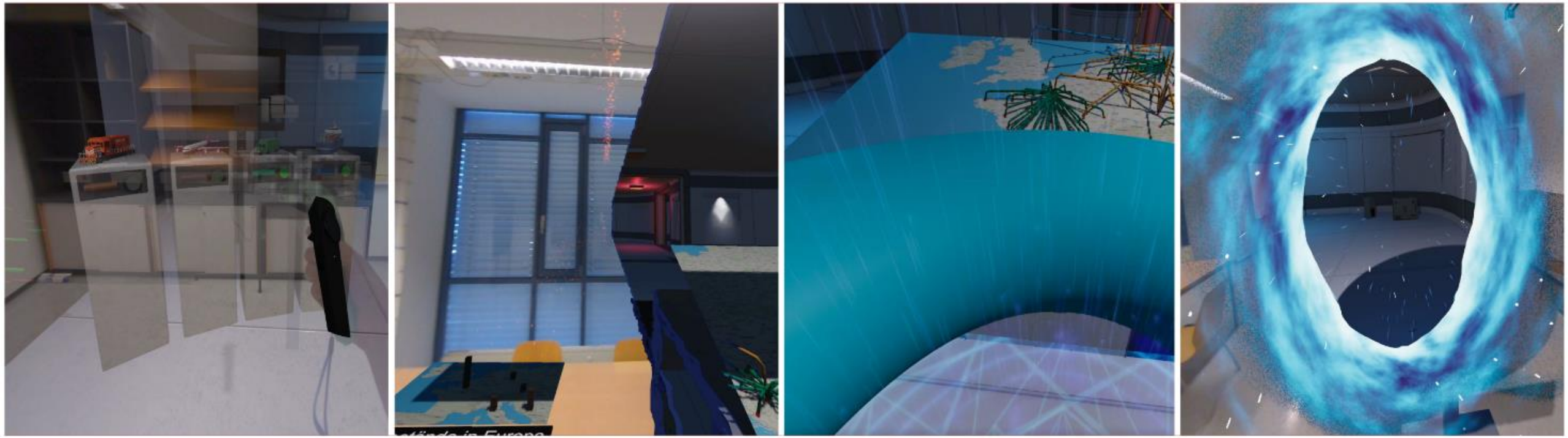
Reality-Virtuality Continuum (RVC)



Cross-Reality(CR) Definition

Transition between or concurrent usage of multiple systems on the RV continuum.

Single-User CR Scenarios



Transition of the environment along the RVC

Single-User CR Scenarios

Interacting with multiple systems located at different points along RVC concurrently

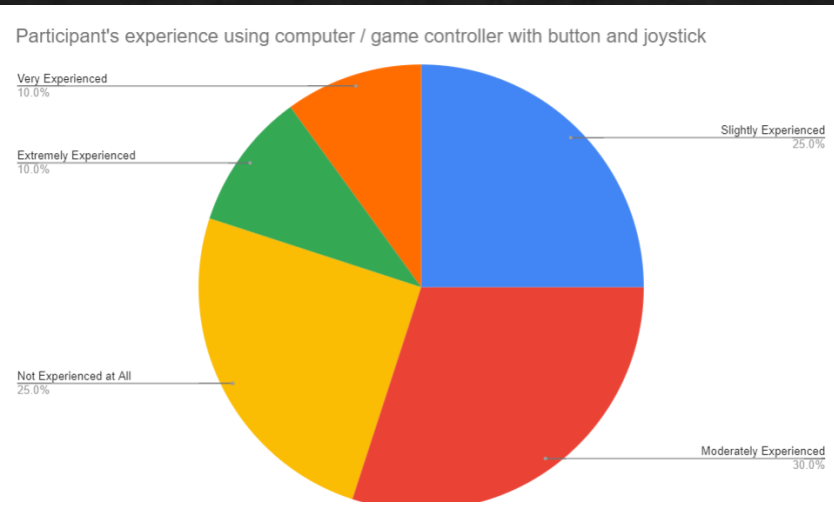
Single-User CR Scenarios

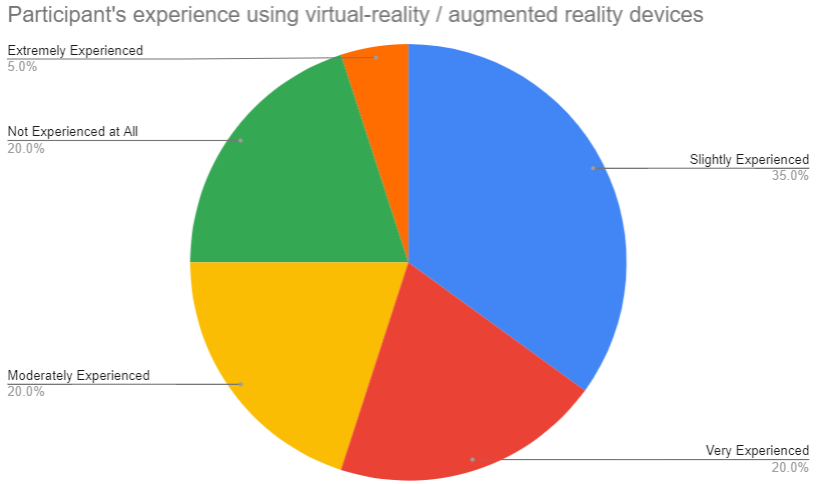
Transition of the virtual objects along the RVC

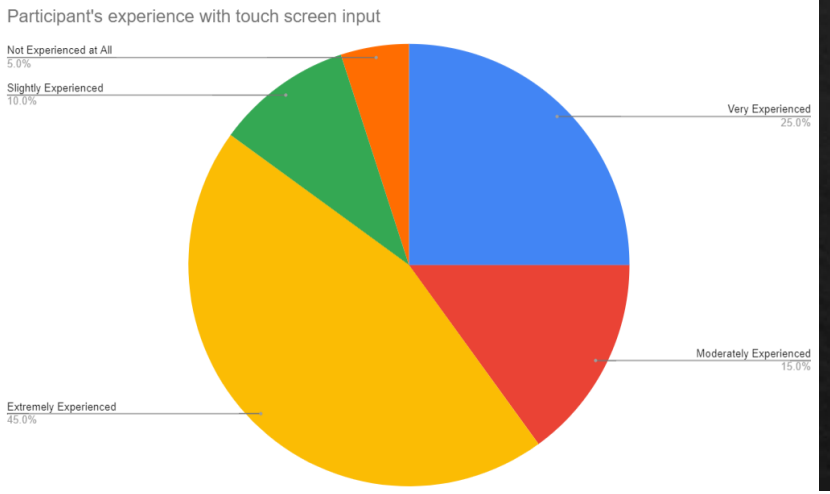
Research Question

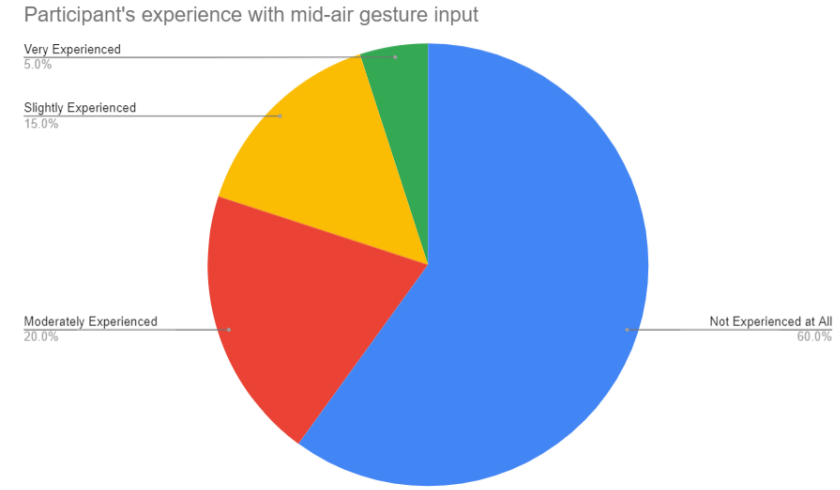
How would user prefer to transition 3D virtual objects between a standard monitor and AR HMD while sitting or standing during a cross-reality (CR) session.

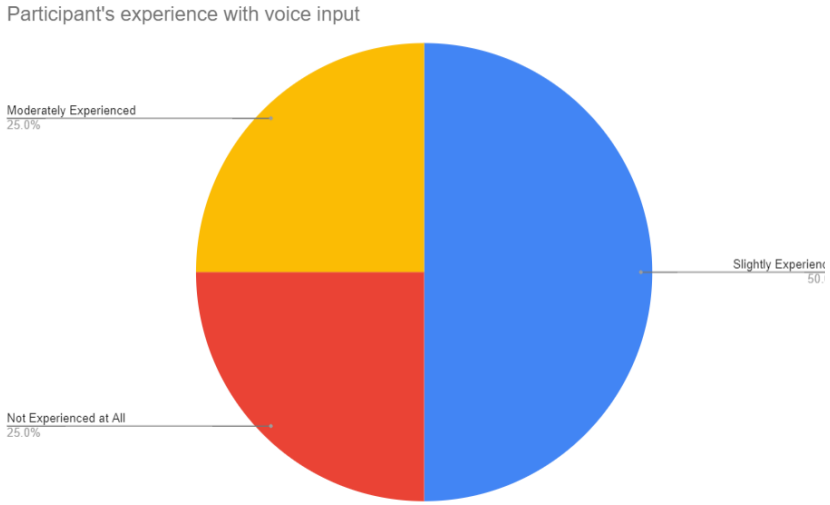
Participants

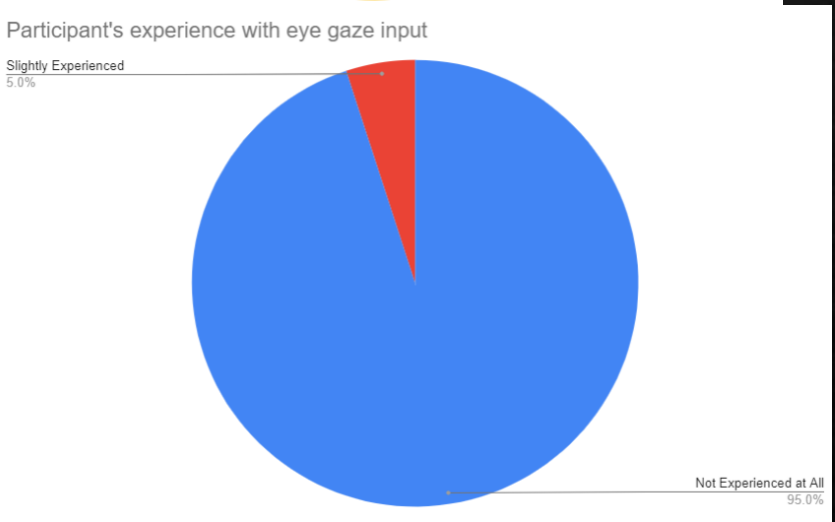




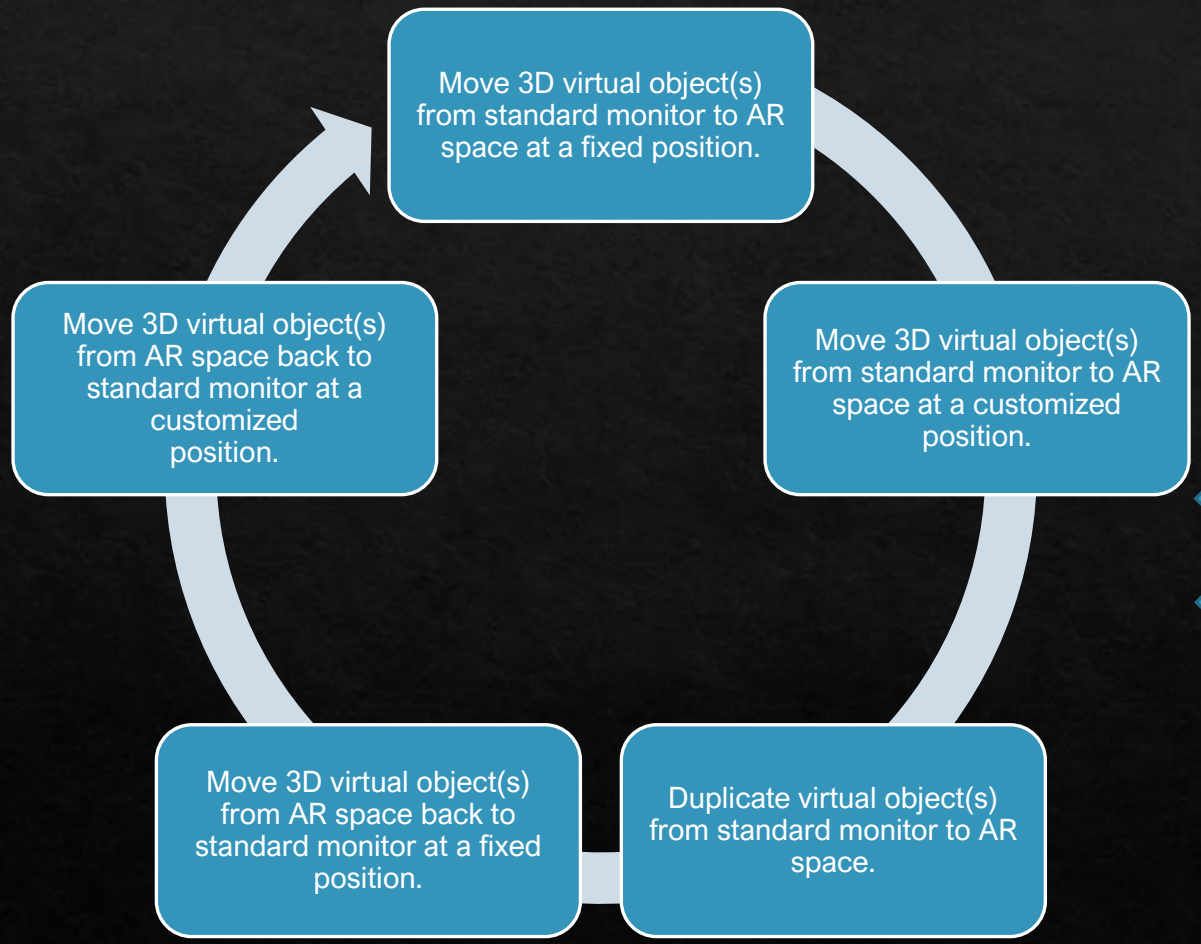








Elicitation Study



×

Sitting / Standing

×

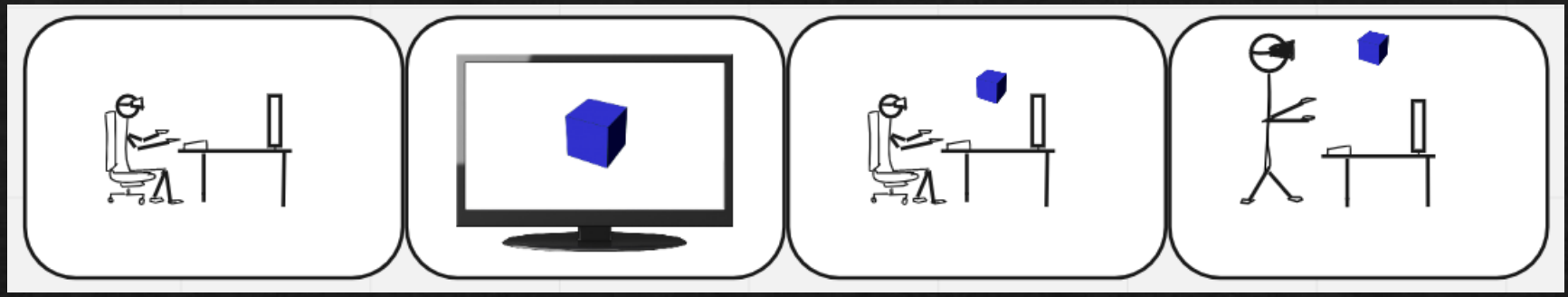
- 1 out of N virtual object
- 3 out of N virtual objects

Elicitation Study

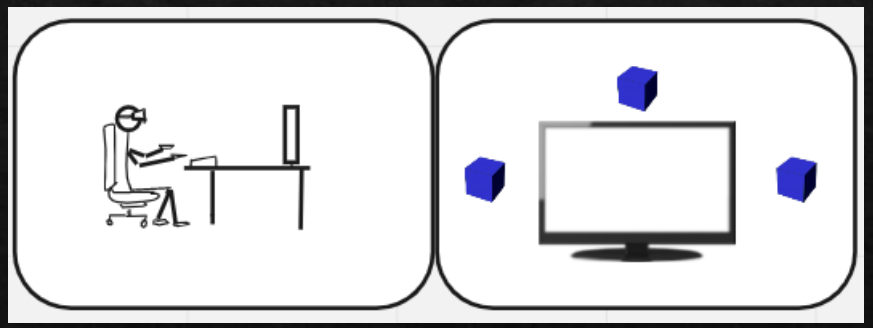
Elicitation Study

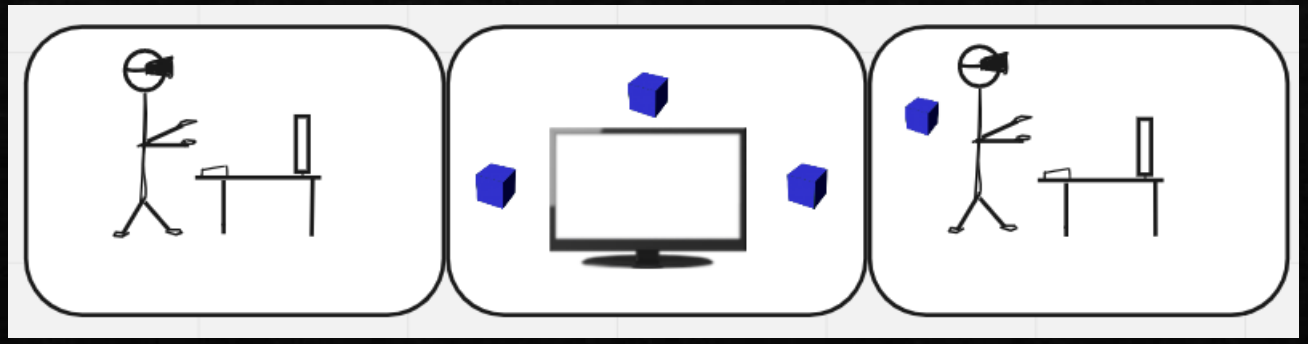
Elicitation Study

Transition to a fixed position



Transition to a customized position





Data Size

20 Participants

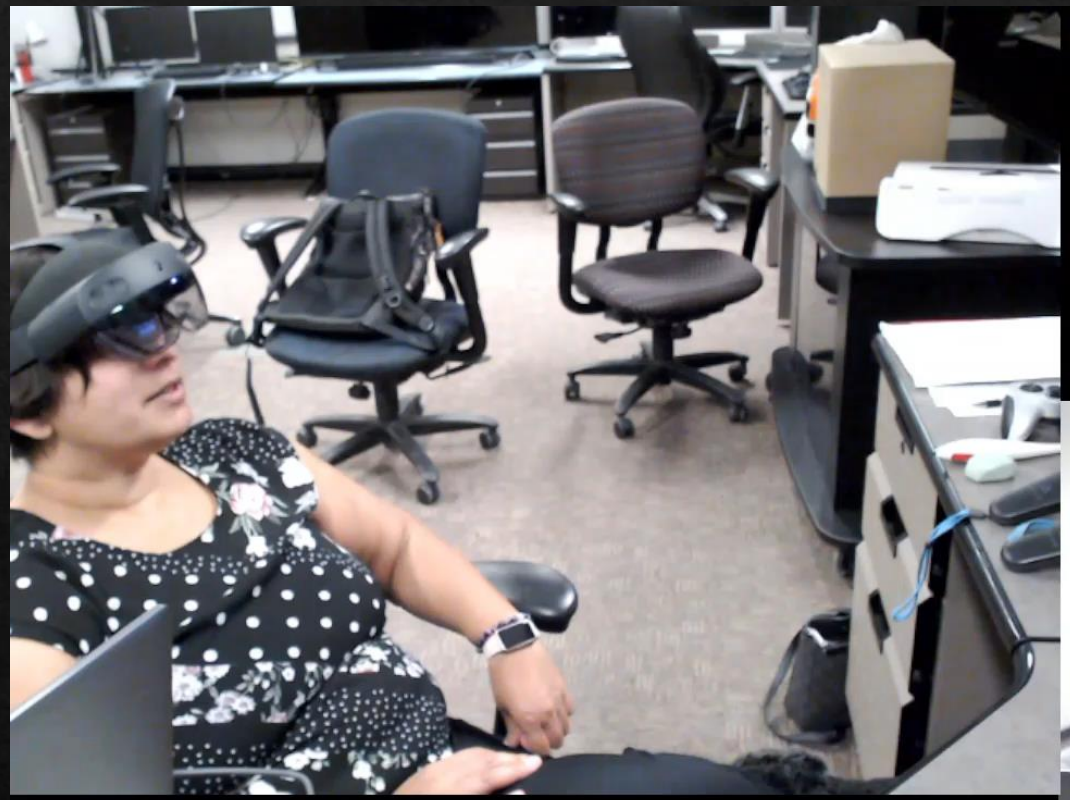
20 Referents

3 Proposals per Referent

Data Analysis – Open Coding

Input Modality Code	Hand Action	Gaze Based Action
TC = Tranditional Controller	Grab	Look
HG = Hand Gesture	Air Tap	Stare = Look and hold
VE = Voice	Tap	Blink
EG = Eye Gaze	Bloom	Close
MC = Motion Controller	Swipe	**Traditional Input Device**
BC = Brain-Computer Interface	Release	Press button
BG = Full Body Gesture	Tap and Hold	Select
Supplements	Throw	Drag
->R = Action going from left to right	Push	Circle
->L = Action going from right to left	Beckon	**Motion Tracking Controller**
->S = Action going towards screen	Drag	Circle
<-S = Action going away from screen	Circle	Select
<--> Action going apart from each other	Flick	Press button
-><- Action going close to each other	Clap	Drag
X2 = Double the action	**Full Body Gesture**	Throw
X3 = Triple the action	Kick	Swipe
->U = Action going from bottom to top	Stamp	
->D = Action going from top to bottom		

Data Analysis



Data Analysis

Participant	Proposal Order	Input Modality Code	Interaction Code
8	1	HG	Grab [R] <-S, Drag [R]
	2	HG	Grab [R] <-S,Drag [R]
	3	EG	Look, Blink, Look, Blink
9	1	HG	Grab [R] <-S
	2	HG	Tap [R], Grab [R] <-S
	3	HG	Tap [R], Tap [R]
10	1	HG	Grab [R] <-S
	2	MC	Select, Drag <-R
	3	HG, VE	Tap [R], "Move"
11	1	HG	Grab [R] <-S, Drag [R]
	2	MC	Select
	3	EG	Stare
12	1	HG	Grab [R] <-S, Drag [R]
	2	MC	Select, Drag <-S
	3	MC	Select, Drag <-S
13	1	HG	Tap [R], Beckon [R]
	2	HG	Grab [R] <-S, Drag [R]
	3	TC	Select
14	1	HG	Grab [R], Drag [R] <-S
	2	MC	Select, Drag <-S
	3	TC	Select, Press button
15	1	HG	Grab [R], Drag [R] <-S
	2	HG	Tap [R], Drag [R]
	3	VE	"Select A, take it out"
16	1	HG	Grab [R], Drag [R] <-S
	2	EG	Stare
	3	VE	"A"

Participant	Proposal Order	Input Modality Code	Interaction Code
8	1	HG	Grab [R] <-S, Drag [R]
	2	HG	Grab [R] <-S,Drag [R]
	3	EG	Look, Blink, Look, Blink
9	1	HG	Grab [R] <-S
	2	HG	Tap [R], Grab [R] <-S
	3	HG	Tap [R], Tap [R]
10	1	HG	Grab [R] <-S
	2	MC	Select, Drag <-R
	3	HG, VE	Tap [R], "Move"
11	1	HG	Grab [R] <-S, Drag [R]
	2	MC	Select
	3	EG	Stare
12	1	HG	Grab [R] <-S, Drag [R]
	2	MC	Select, Drag <-S
	3	MC	Select, Drag <-S
13	1	HG	Tap [R], Beckon [R]
	2	HG	Grab [R] <-S, Drag [R]
	3	TC	Select
14	1	HG	Grab [R], Drag [R] <-S
	2	MC	Select, Drag <-S
	3	TC	Select, Press button
15	1	HG	Grab [R], Drag [R] <-S
	2	HG	Tap [R], Drag [R]
	3	VE	"Select A, take it out"
16	1	HG	Grab [R], Drag [R] <-S
	2	EG	Stare
	3	VE	"A"

Data Analysis

Generic Participant Number		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Proposals	Proposal 1	Grab	Grab	Grab, Drag	Tap, Beckon	Brain	Grab	Tap, Beckon	Grab, Drag	Grab	Grab
	Proposal 2	Tap	Voice	Grab	Select, Drag	Select	Stare, Look	Look, Blink	Grab, Drag	Tap, Grab	Select, Drag
	Proposal 3	Stare, Look	Select, Drag	Tap, Beckon	Voice	Select	Tap	Voice	Look, Blink	Tap	Tap, Voice
Participant's Input Modality Final Set		HG, EG	HG, VE, MC	HG	HG, MC, VE	BC, MC	HG, EG	HG, EG, VE	HG, EG	HG	HG, MC, VE
Generic Participant		P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
Proposals	Proposal 1	Grab, Drag	Grab, Drag	Tap, Beckon	Grab, Drag	Grab, Drag	Grab, Drag	Grab, Drag	Grab, Drag	Grab, Drag	Select, Drag
	Proposal 2	Select	Select, Drag	Grab, Drag	Select, Drag	Tap, Drag	Stare	Select	Select, Drag	Voice	Grab, Drag
	Proposal 3	Stare	Select, Drag	Select	Select, Press button	Voice	Voice	Tap	Select, Press button	Stare	Tap
Participant's Input Modality Final Set		HG, MC, EG	HG, MC	HG, TC	HG, MC, TC	HG, VE	HG, EG, VE	HG, TC	HG, TC	HG, VE, EG	TC, HG
Final Set by Number of Participants Who Proposed Interaction		Grab(20), Drag(24), Tap(15), Select(17), Voice(7), Stare(7), Press button(2), Beckon(7), Look(6), Blink(2), Brain(1)									
Final Set by Number of Participants Who Proposed Input Modality		HG(19), EG(7), VE(7), MC(7), BC(1), TC(5)									

Data Analysis

Generic Participant Number		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Proposals	Proposal 1	Grab	Grab	Grab, Drag	Tap, Beckon	Brain	Grab	Tap, Beckon	Grab, Drag	Grab	Grab
	Proposal 2	Tap	Voice	Grab	Select, Drag	Select	Stare, Look	Look, Blink	Grab, Drag	Tap, Grab	Select, Drag
	Proposal 3	Stare, Look	Select, Drag	Tap, Beckon	Voice	Select	Tap	Voice	Look, Blink	Tap	Tap, Voice
Participant's Input Modality Final Set		HG, EG	HG, VE, MC	HG	HG, MC, VE	BC, MC	HG, EG	HG, EG, VE	HG, EG	HG	HG, MC, VE
Generic Participant		P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
Proposals	Proposal 1	Grab, Drag	Grab, Drag	Tap, Beckon	Grab, Drag	Grab, Drag	Grab, Drag	Grab, Drag	Grab, Drag	Grab, Drag	Select, Drag
	Proposal 2	Select	Select, Drag	Grab, Drag	Select, Drag	Tap, Drag	Stare	Select	Select, Drag	Voice	Grab, Drag
	Proposal 3	Stare	Select, Drag	Select	Select, Press button	Voice	Voice	Tap	Select, Press button	Stare	Tap
Participant's Input Modality Final Set		HG, MC, EG	HG, MC	HG, TC	HG, MC, TC	HG, VE	HG, EG, VE	HG, TC	HG, TC	HG, VE, EG	TC, HG
Final Set by Number of Participants Who Proposed Interaction		Grab(20), Drag(24), Tap(15), Select(17), Voice(7), Stare(7), Press button(2), Beckon(7), Look(6), Blink(2), Brain(1)									
Final Set by Number of Participants Who Proposed Input Modality		HG(19), EG(7), VE(7), MC(7), BC(1), TC(5)									

Consensus – Agreement Rate

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

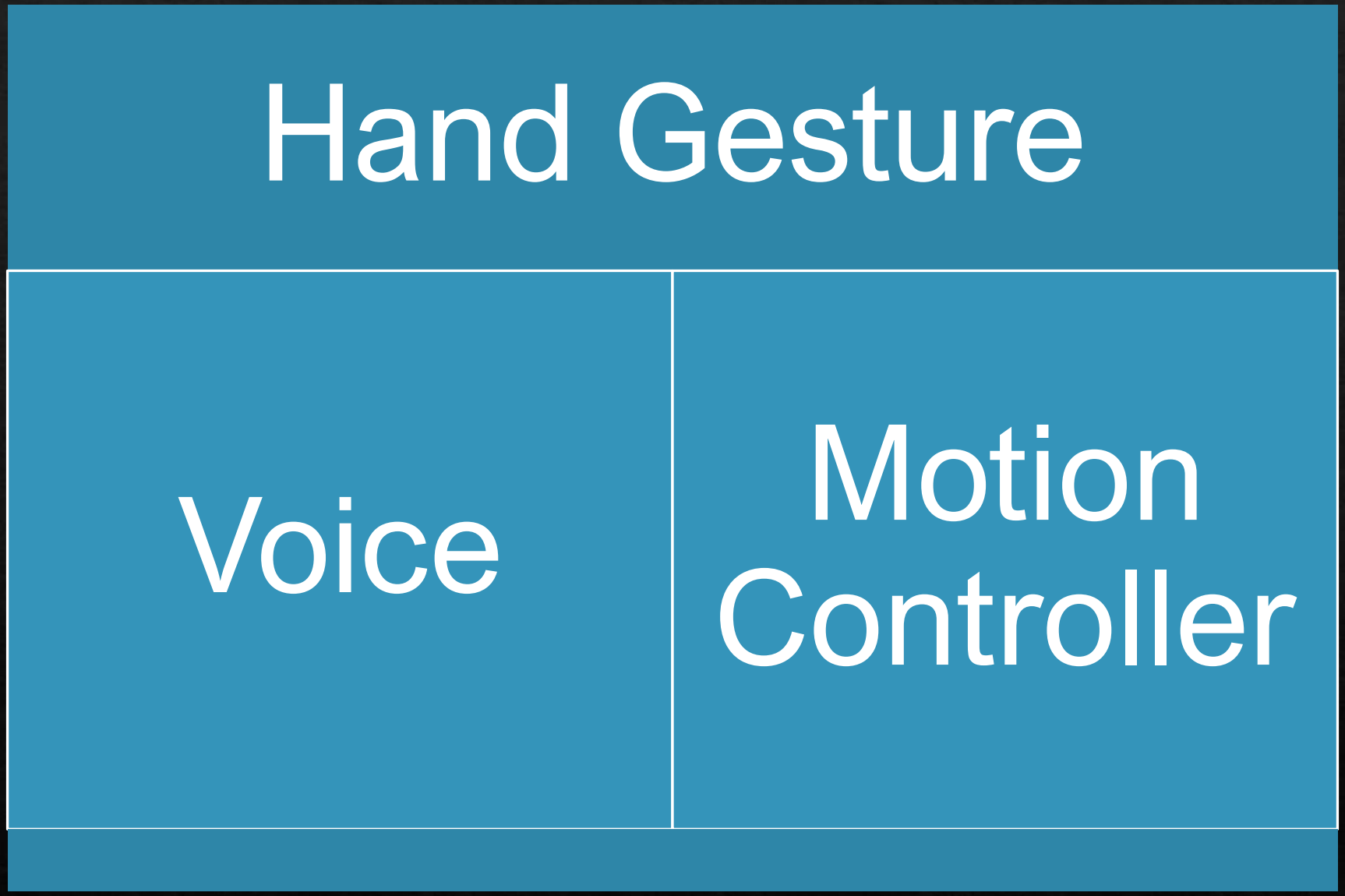
Data Analysis

Generic Participant Number		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Proposals	Proposal 1	Grab	Grab	Grab, Drag	Tap, Beckon	Brain	Grab	Tap, Beckon	Grab, Drag	Grab	Grab
	Proposal 2	Tap	Voice	Grab	Select, Drag	Select	Stare, Look	Look, Blink	Grab, Drag	Tap, Grab	Select, Drag
	Proposal 3	Stare, Look	Select, Drag	Tap, Beckon	Voice	Select	Tap	Voice	Look, Blink	Tap	Tap, Voice
Participant's Input Modality Final Set		HG, EG	HG, VE, MC	HG	HG, MC, VE	BC, MC	HG, EG	HG, EG, VE	HG, EG	HG	HG, MC, VE
Generic Participant		P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
Proposals	Proposal 1	Grab, Drag	Grab, Drag	Tap, Beckon	Grab, Drag	Grab, Drag	Grab, Drag	Grab, Drag	Grab, Drag	Grab, Drag	Select, Drag
	Proposal 2	Select	Select, Drag	Grab, Drag	Select, Drag	Tap, Drag	Stare	Select	Select, Drag	Voice	Grab, Drag
	Proposal 3	Stare	Select, Drag	Select	Select, Press button	Voice	Voice	Tap	Select, Press button	Stare	Tap
Participant's Input Modality Final Set		HG, MC, EG	HG, MC	HG, TC	HG, MC, TC	HG, VE	HG, EG, VE	HG, TC	HG, TC	HG, VE, EG	TC, HG
Final Set by Number of Participants Who Proposed Interaction		Grab(20), Drag(24), Tap(15), Select(17), Voice(7), Stare(7), Press button(2), Beckon(7), Look(6), Blink(2), Brain(1)									
Interaction Proposed by Most Amount of People		Drag (Agreement Rate: 0.136)| Grab, Select, Tap (Consensus Threshold: 9.818)									

$$AR = \frac{\frac{1}{2}\times 20\times 19+\frac{1}{2}\times 24\times 23+\frac{1}{2}\times 15\times 14+\frac{1}{2}\times 17\times 16+\frac{1}{2}\times 7\times 6+\frac{1}{2}\times 7\times 6+\frac{1}{2}\times 2\times 1+\frac{1}{2}\times 7\times 6+\frac{1}{2}\times 6\times 5+\frac{1}{2}\times 2\times 1}{\frac{1}{2}\times 108\times (108\ -1)}$$

$$= 0.136$$

Consensus Input Modality



Consensus Interaction Set: Main

Drag

Tap

Grab

Consensus Interaction Set: Supplement

Voice

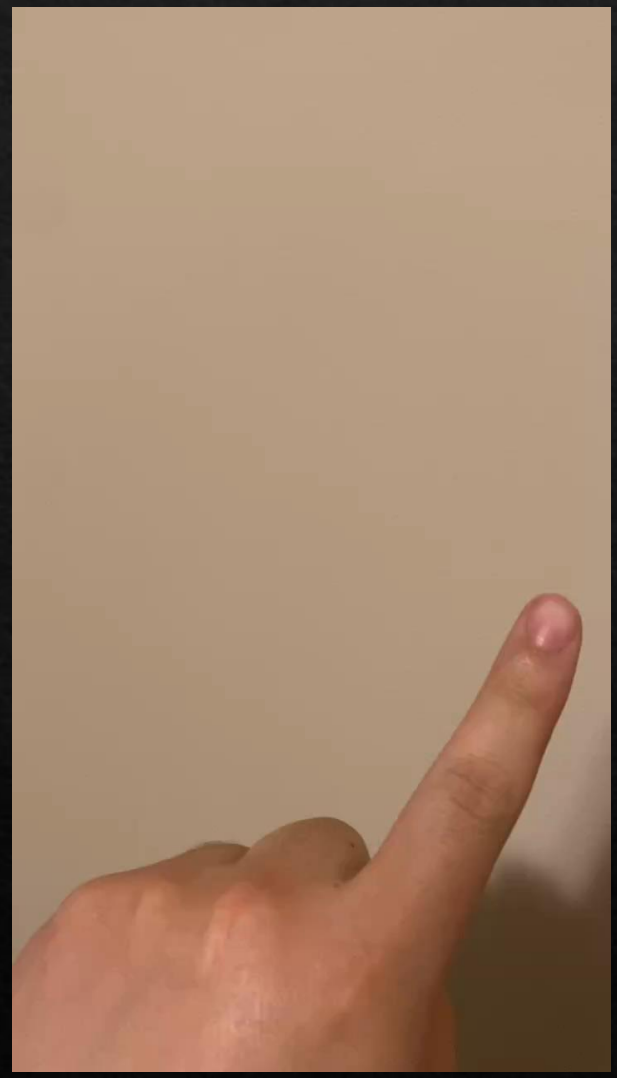
Select

Consensus Interaction Set: Transition Virtual Object to Monitor

Throw

Swipe

Consensus Interaction Set: Duplication or Grouping



Circle

Future Work

Close/Open Elicitation Study

User Study

Case Study

Thank You!