SFU SIMON FRASER UNIVERSITY
ENGAGING THE WORLD

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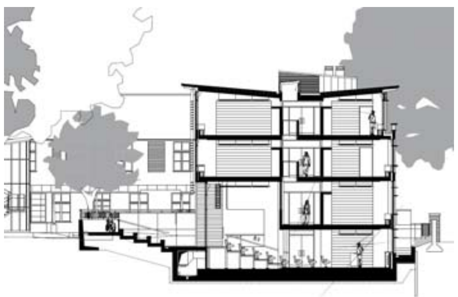
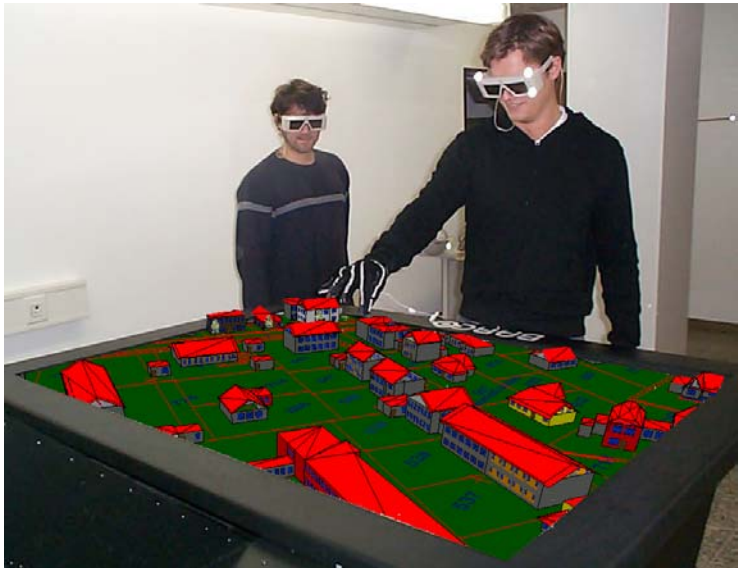
Experience Before Construction: Immersive Virtual Reality Design Tools for Architectural Practice

Design Representation in Architectural Practice



Immersive Virtual Reality in Architectural Practice



Research Questions

RQ 1) What usage scenarios would architects want to use IVR for?

RQ 2) What are the system requirements of an IVR representation tool for different usage scenarios?

RQ 3) How can we design an IVR architectural representation interface that fulfills the system requirements for most of our usage scenarios?

RQ 4) How does our IVR architectural representation interface compare to existing interfaces?

Arayici et. al., (2011)

Project Phases

Explore — Investigated current design process and uncovered usage scenarios and system requirements

↓

Design — Iteratively designed the interface with Architects at Perkins + Will

↓

Evaluate — Tested the interface based on requirements

Methods

Interviews: Explore current design representations in process and presentation
Explore IVR representation usage scenarios

Participants: 7 professionals in the field of architecture
Procedure: 1 hour interview with demo of Oculus Rift

Focus Groups: Explore current design representations in process and presentation
Explore IVR usage scenarios and interface requirements

Participants: 2 groups at Perkins + Will (one junior/ one senior)
Procedure: 2 hour focus group with questions and activities

Explore → Design → Evaluate

Immersive Modeling Tool

IP3: “So you can kind of move around the building **with this perspective, and be designing it,** because I do wonder if you would actually create a different building... or see it in a different way.”

Usage Scenarios

Scale Assessment

JFP2: “When we did that simple cardboard section cut-out and put it in the atrium. As much as you think you understand scale, when you get refreshers like that, **you’re like, wow this is big**. You know its tall, but...”

Explore → Design → Evaluate

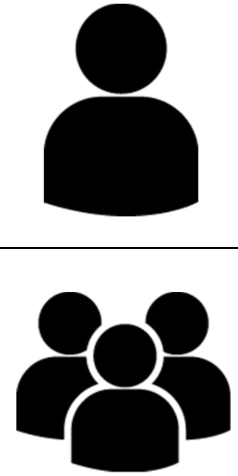
Future Occupant Testing

SFP4: "I mean I could see something where you have an exit questionnaire/exit interview when there's an experience being had, and **you can gather the opinion and you consider the opinion**."

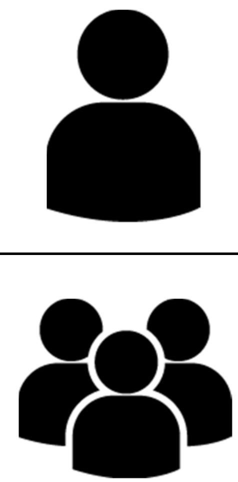
Usage Scenarios

Usage Scenarios

Process (in house): Using immersive virtual reality to assist with design tasks



Presentation (with clients): Communicating the design to clients and stakeholders



Explore → Design → Evaluate

System Requirements

Process

Individual Users

Immersive Modeling Tools
Virtual Site Visit
Scale Assessment
Design Annotation
Conflict Detection Tasks

Design Review

Multiple Users

Precedent Observation
3D Data Visualization
Isovist Viewing
Experiential Evaluation

Presentation

Individual Users

Promotional Simulation

Future Occupant Testing

Guided Group Presentation

Multiple Users

Explore → Design → Evaluate

Requirements

Functional Requirements	Non-functional Requirements
Visual Display	Facilitate Sensory Immersion Allow Social Interaction Minimize Motion Sickness Maximize Affordability Maximize Ease of Setup
Locomotion Interface	Facilitate Sensory Immersion Maximize Learnability Maximize Controllability Facilitate User Orientation & Navigation Minimize Motion Sickness Provide Hands Free Locomotion Maximize Affordability Maximize Ease of Setup
Conversion Process	Maximize Ease of Setup

Visual Display

Requirements:

Facilitate Sensory Immersion
Allow Social Interaction
Minimize Motion Sickness
Maximize Affordability
Maximize Ease of Setup

Single User Scenarios

Oculus Rift DK2 HMD

Multi-User Scenarios

Portable HD 3D Projector

Ermi et. al., (2011)

Explore ⟶ Design ⟶ Evaluate

Locomotion Interface Design

Requirements:

- Facilitate Sensory Immersion
- Maximize Learnability
- Maximize Controllability
- Maximize Ease of Setup
- Minimize Motion Sickness
- Provide Hands Free Locomotion
- Maximize Affordability
- Facilitate User Orientation/Navigation

Swopper Chair

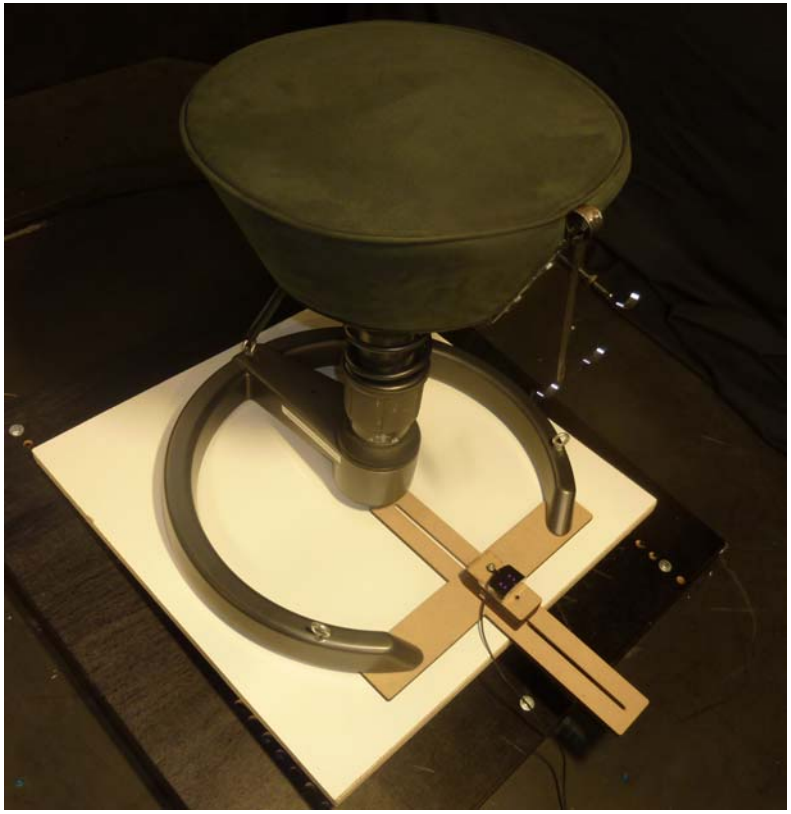
Track IR 4

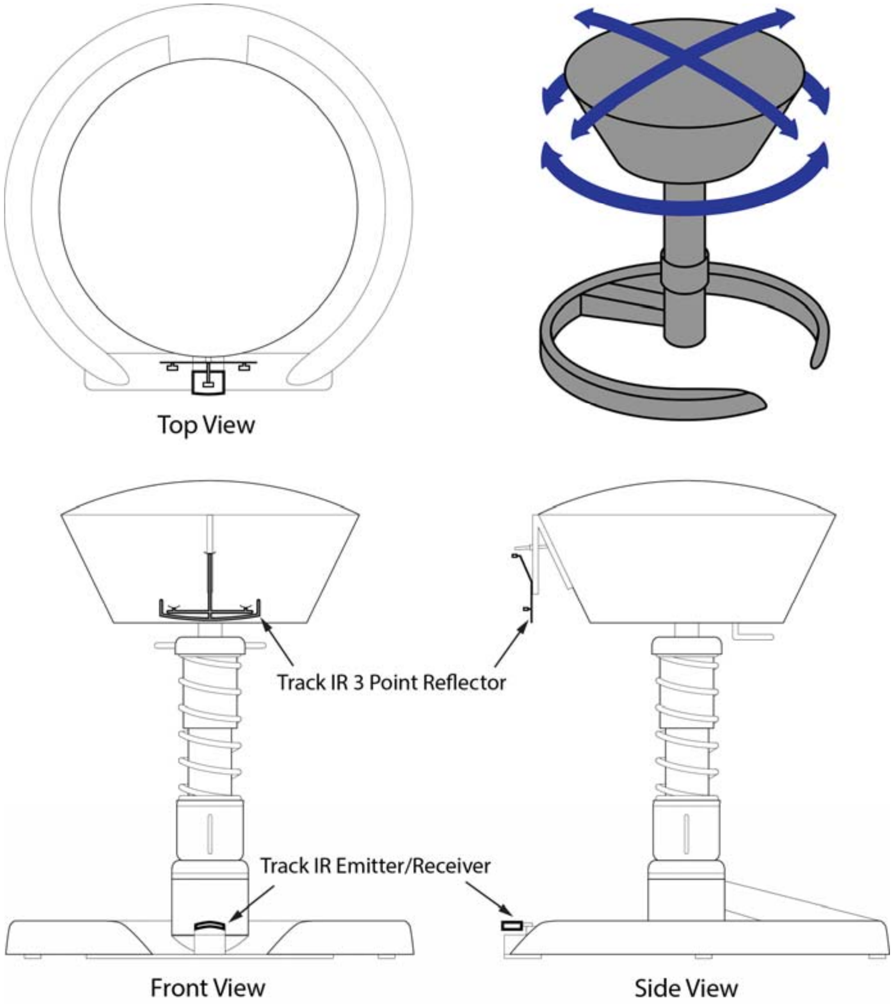
Beckhaus et. al., (2007)

Explore ⟶ **Design** ⟶ Evaluate

Locomotion Interface Design

NaviChair





Explore → **Design** → Evaluate

Locomotion Interface Design

BIM/3D Model Conversion

REVIT → 3DS MAX → unity

Yifan (2014)

Explore → **Design** → Evaluate

Experimental Evaluation

Functional Requirements	Non-functional Requirements
Visual Display	**Facilitate Sensory Immersion** Allow Social Interaction **Minimize Motion Sickness** Maximize Affordability Maximize Ease of Setup
Locomotion Interface	**Facilitate Sensory Immersion** **Maximize Learnability** **Maximize Controllability** **Facilitate User Orientation & Navigation** Allow Social Interaction **Minimize Motion Sickness** Provide Hands Free Locomotion Maximize Affordability Maximize Ease of Setup
Conversion Process	Ease of Setup

Explore ⟶ Design ⟶ **Evaluate**

Independent Variables

Experiment Research Questions

Exp RQ1) How do the NaviChair and joystick locomotion interfaces compare in terms of user performance on measures of **spatial orientation**, and ratings of **motion sickness**, **immersion**, **intuitiveness**, and **controllability**?

Exp RQ1) How do the HMD and 3D projection screen visual displays compare in terms of user performance on measures of **spatial orientation**, and ratings of **motion sickness** and **immersion**?

Exp RQ1) What interface preferences do users have for an IVR architectural design review scenario and do they believe our IVR representation tool would be useful?

Exp RQ1) What feedback do users have on the NaviChair locomotion interface and how might it be improved?

Explore ⟶ Design ⟶ **Evaluate**

Experimental Design

Balanced Mixed Factorial Design (2x2)

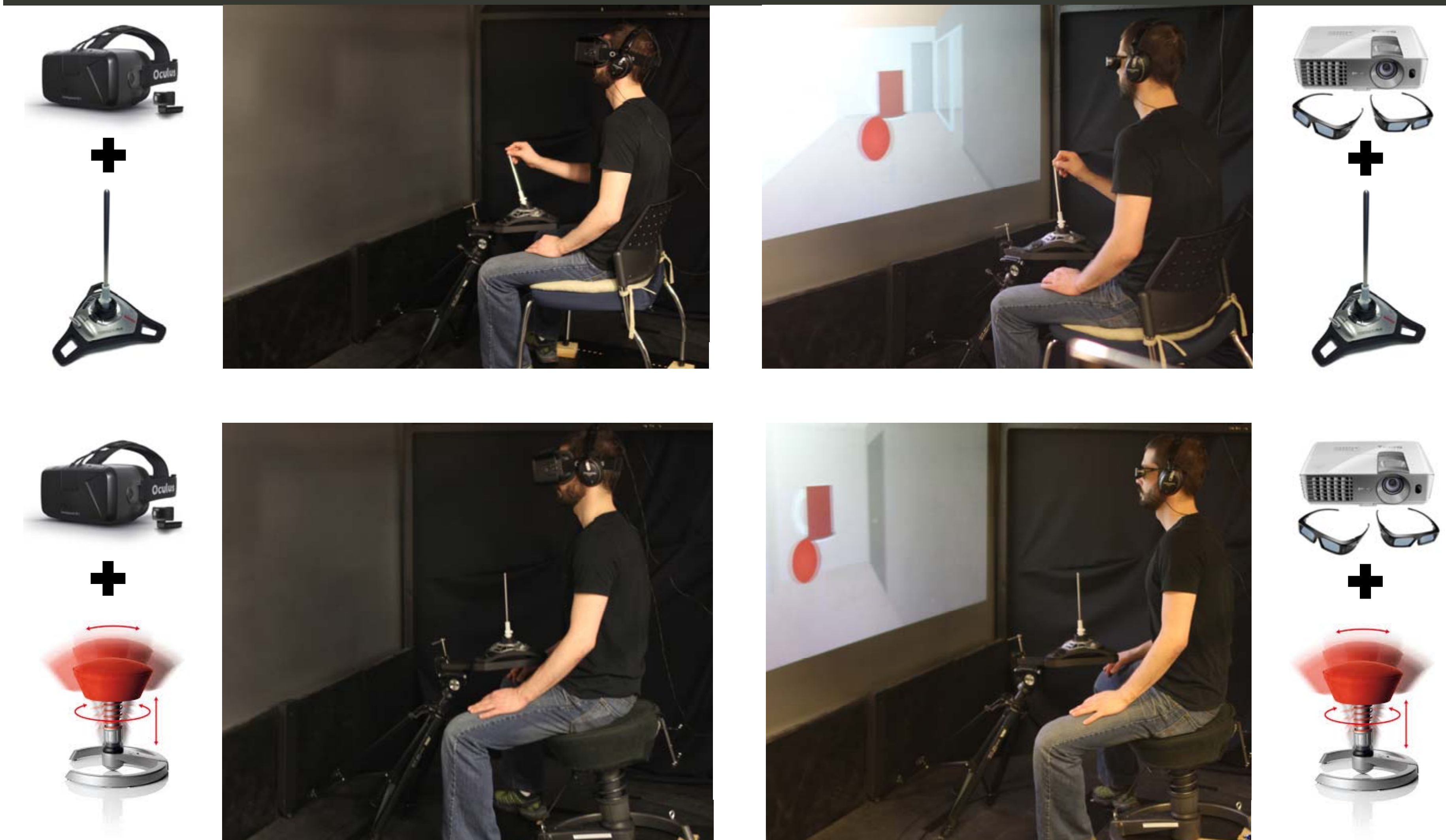
Participants: 32 SFU students (17 Males, 15 Females)
Age Range: 19 – 34 (Mean = 23.9)

Locomotion Interface evaluated within-subjects (NaviChair and joystick)

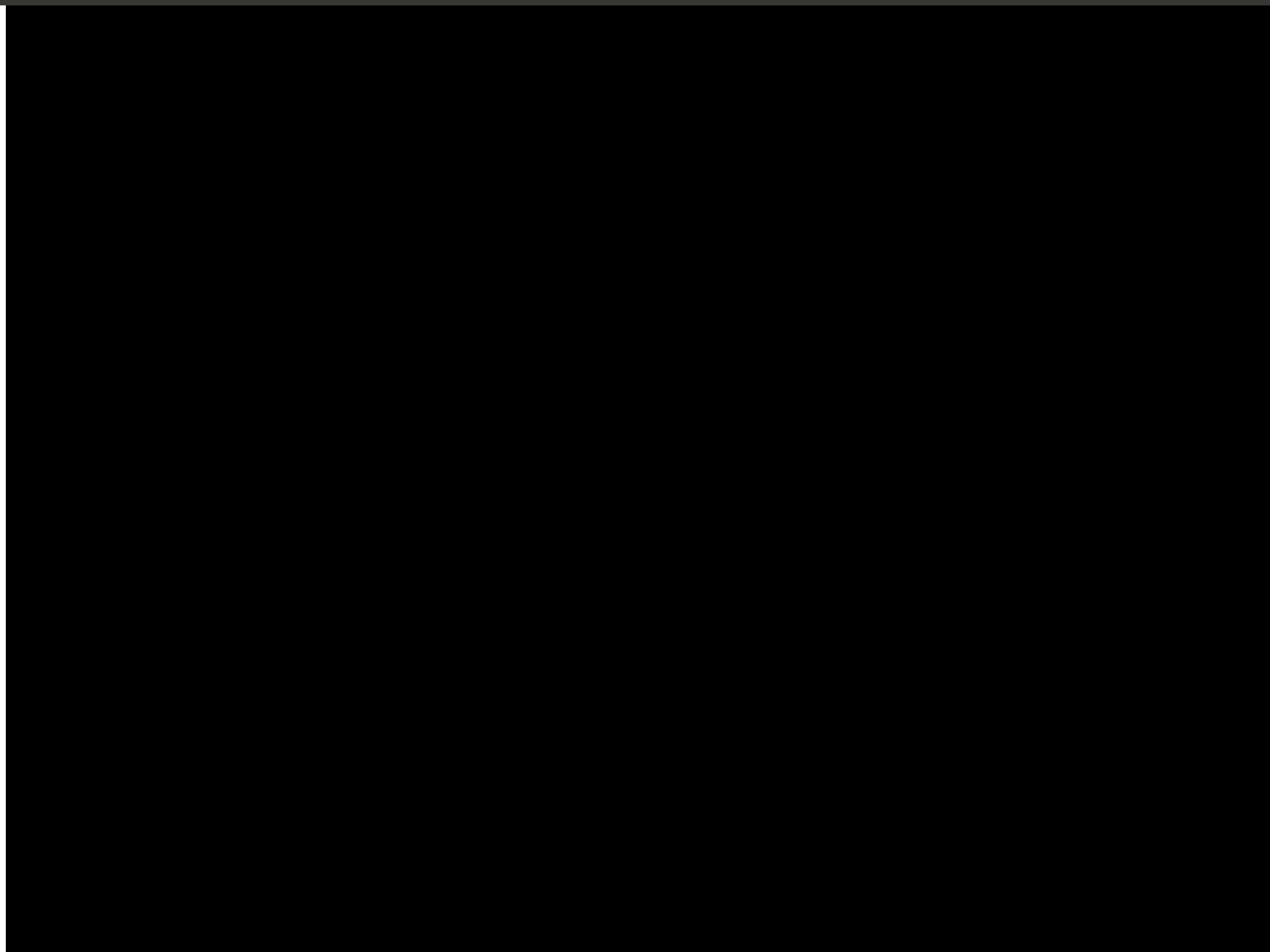
Visual Display divided between-subjects (16 participants Oculus Rift, 16 participants 3D projection screen

Explore ⟶ Design ⟶ **Evaluate**

Main Experiment Conditions

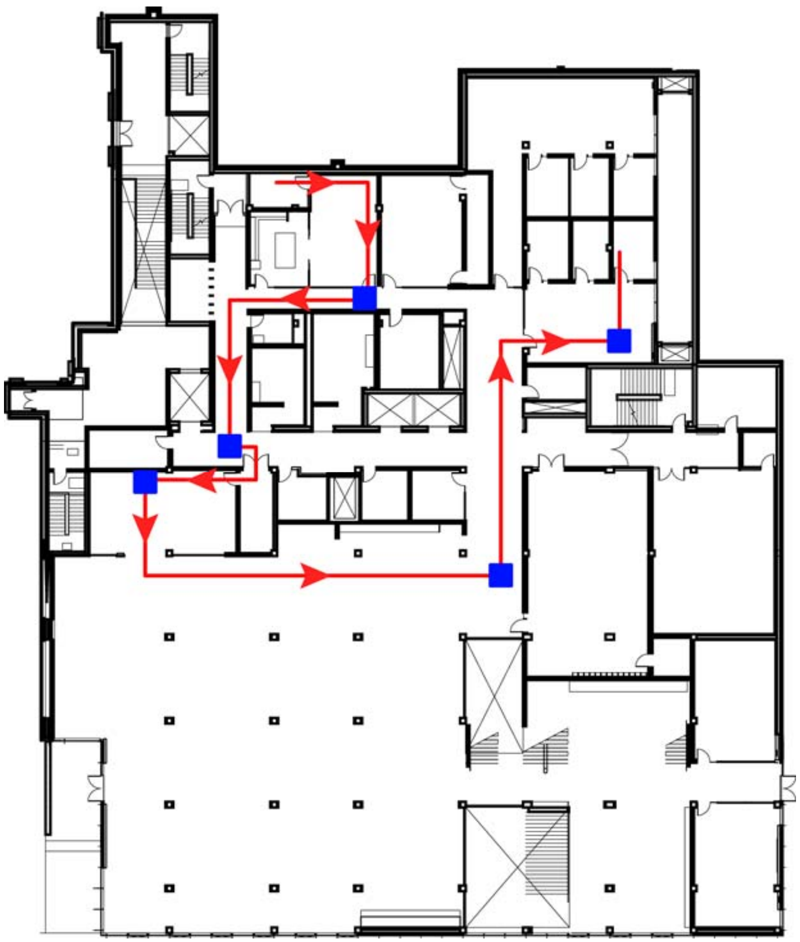


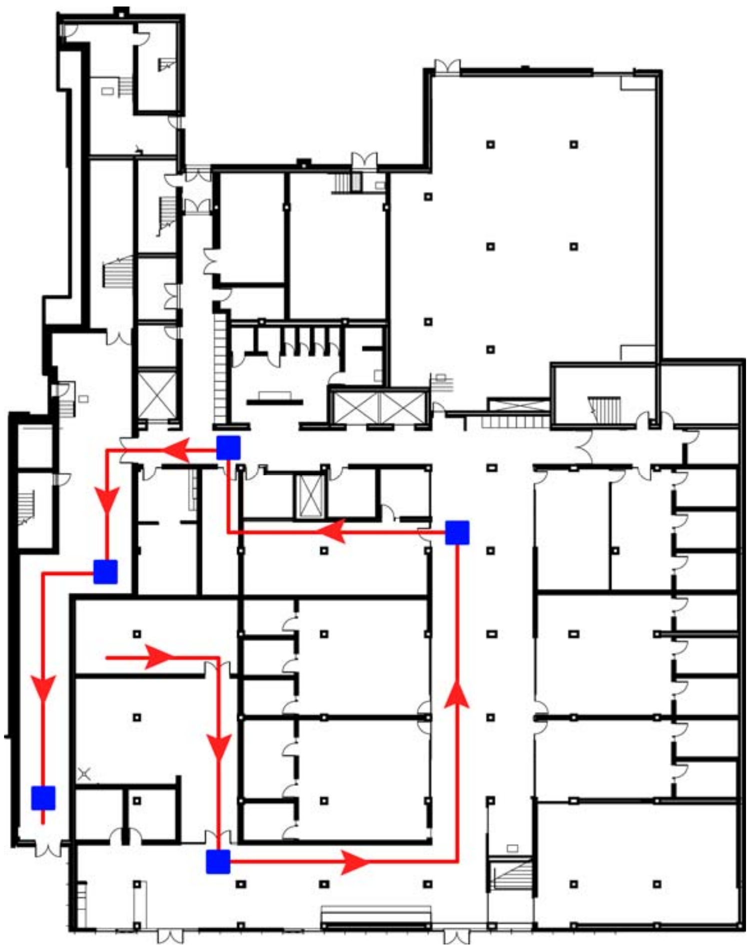
Main Experiment Environment



Explore → Design → **Evaluate**

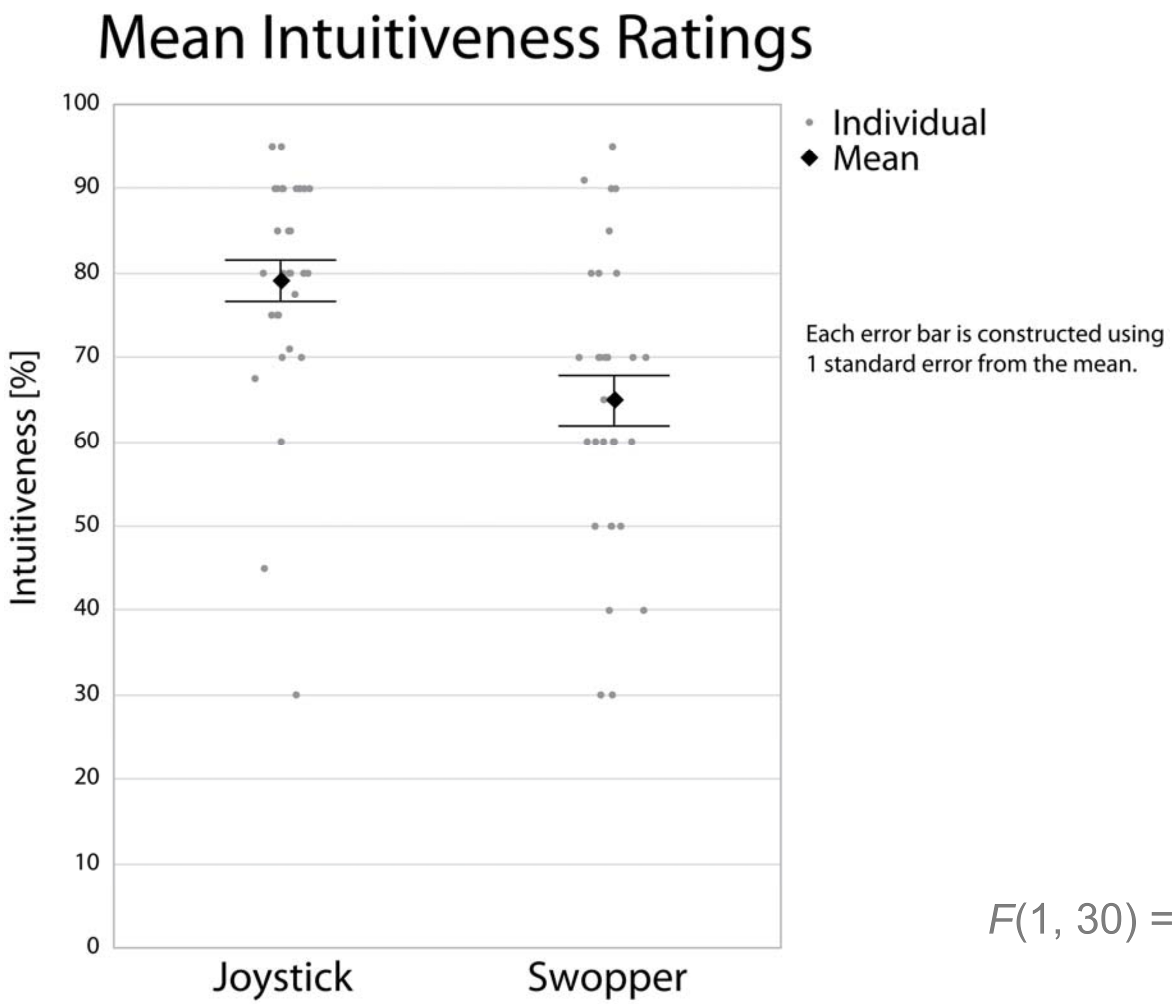
Main Experiment Paths





Explore ⟶ Design ⟶ **Evaluate**

Results

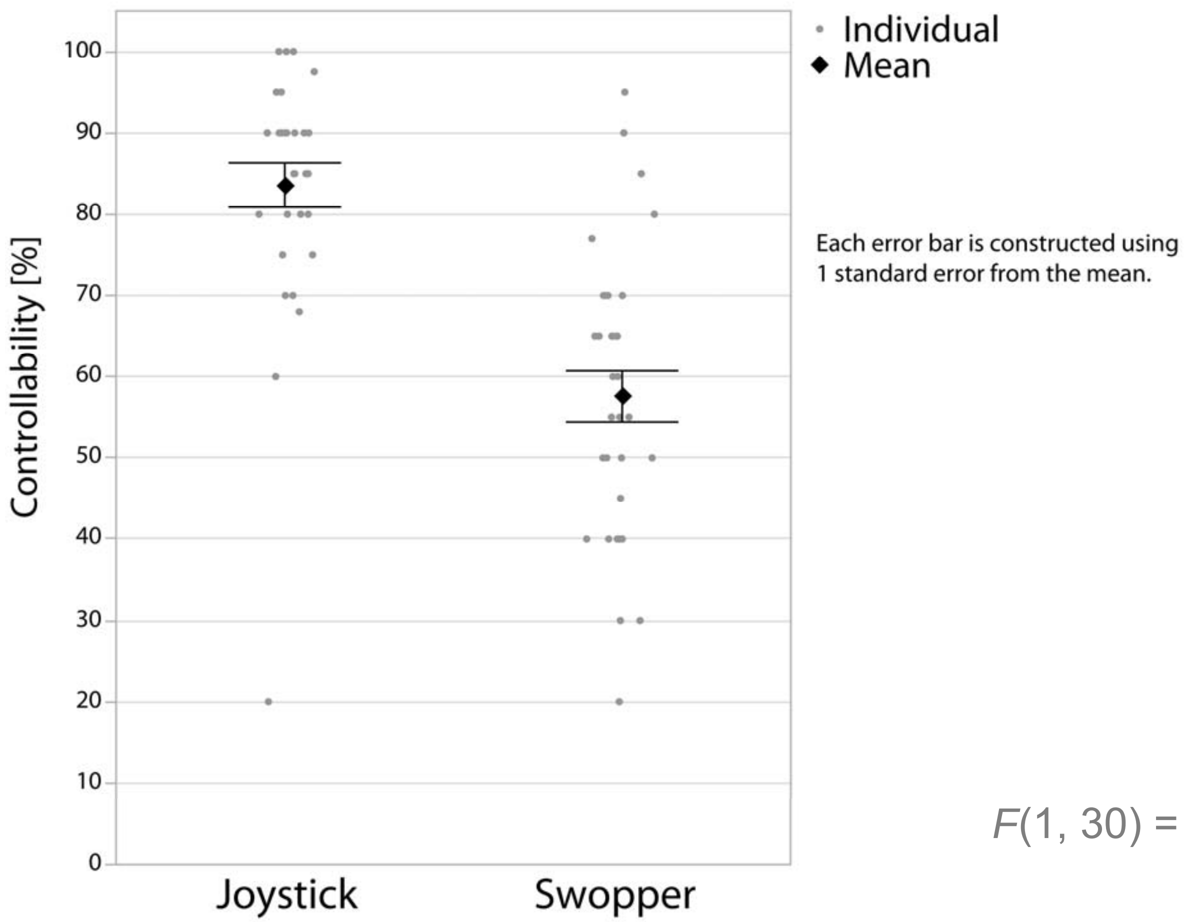


Joystick intuitiveness rated higher

$F(1, 30) = 23.065$, $p < .001$, $\eta 2 = .435$

Results

Mean Controllability Ratings

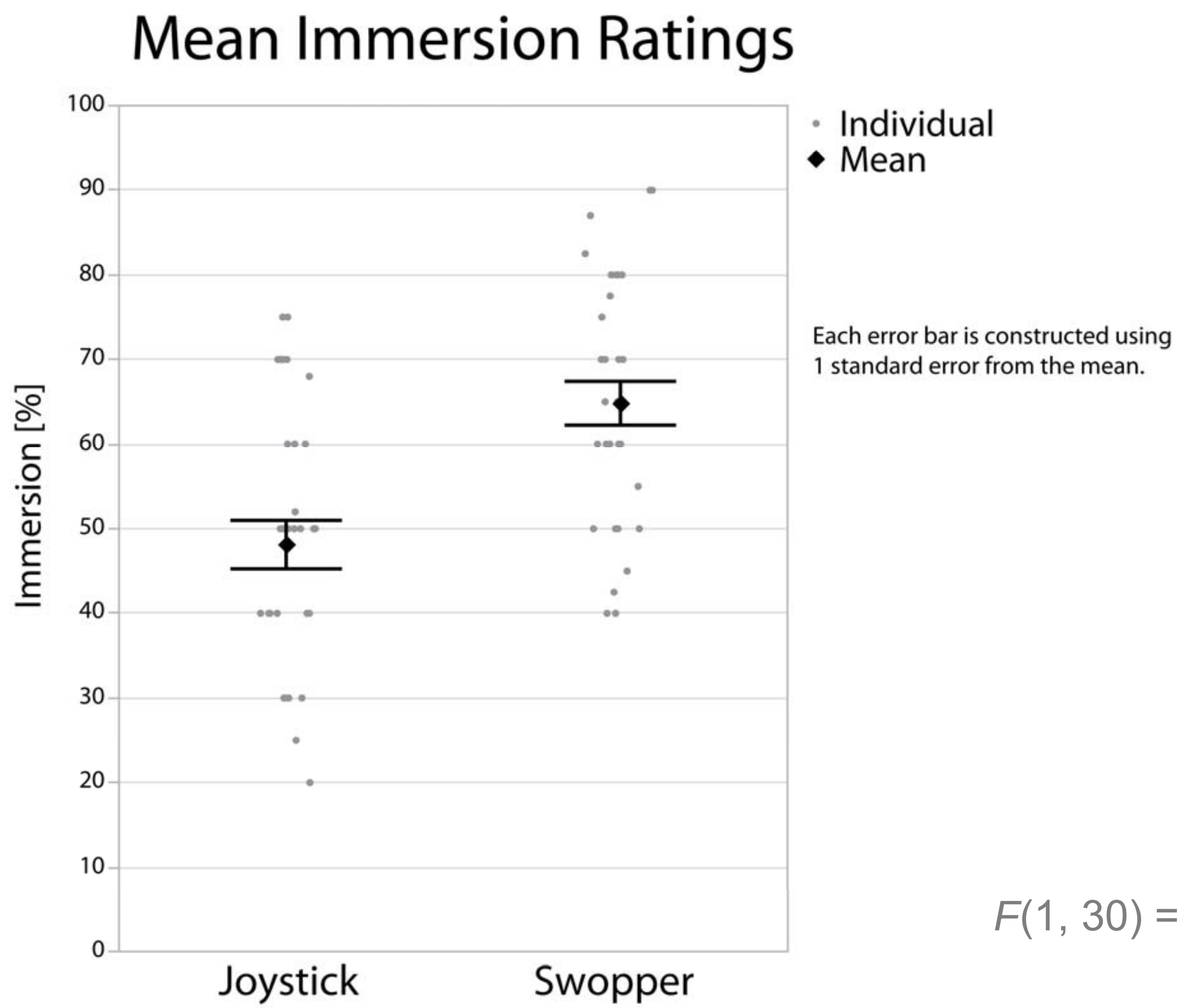


Joystick controllability rated higher

$F(1, 30) = 50.610$, $p < .001$, $\eta 2 = .628$

Explore ⟶ Design ⟶ **Evaluate**

Results



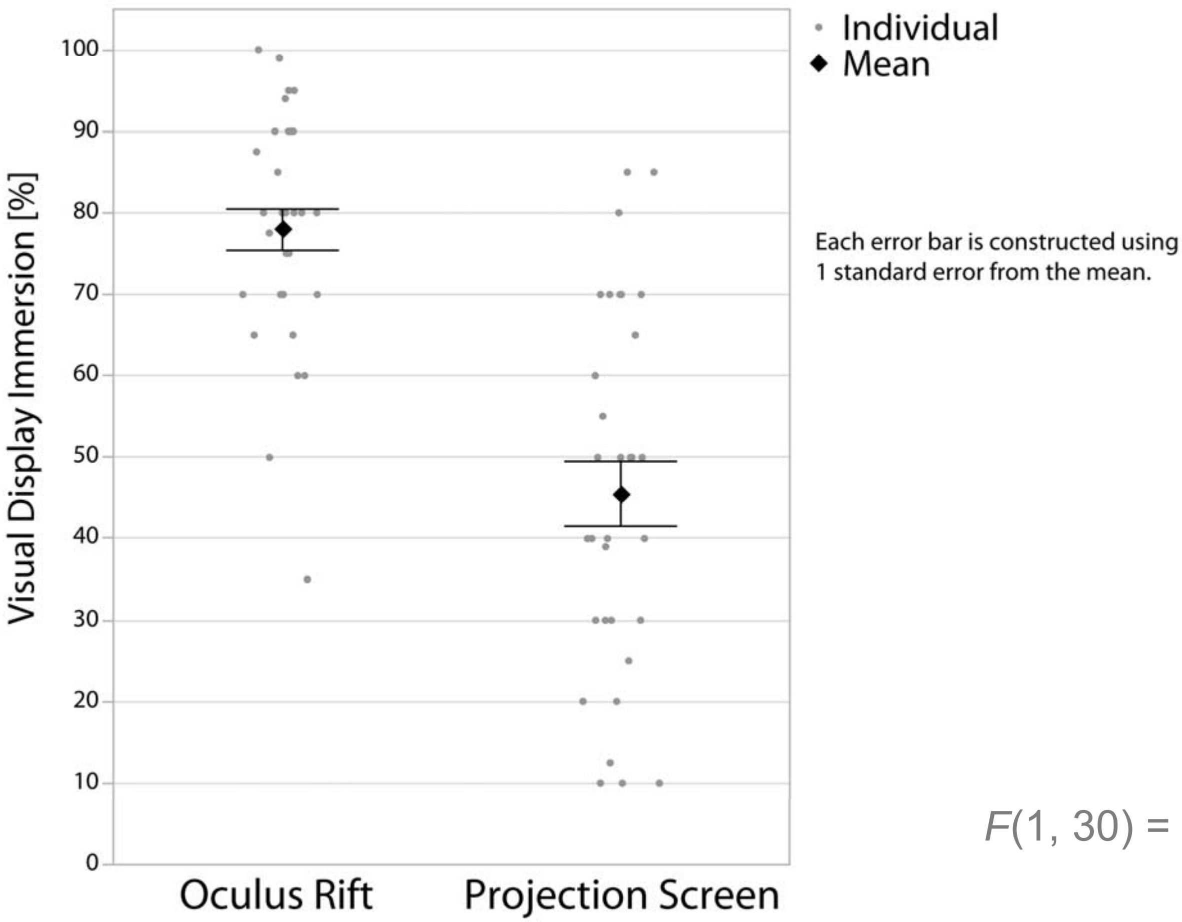
NaviChair immersion rated higher

$F(1, 30) = 25.854$, $p < .001$, $\eta2 = .463$

Explore → Design → **Evaluate**

Results

Mean Visual Display Immersion Ratings

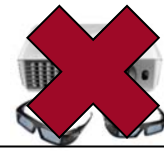


Oculus Rift immersion rated higher

$F(1, 30) = 5.633$, $p = .024$, $\eta 2 = .158$

Explore → Design → **Evaluate**

Results

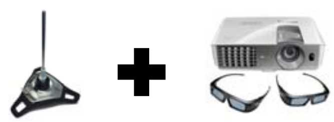
Motion Sickness			$F(1, 30) = 10.189$, $p = .003$, $\eta2 = .254$
Average Pointing Error			$F(1, 139) = 4.500$, $p = .036$, $\eta2 = .031$
Immersion			$F(1, 30) = 5.633$, $p = .024$, $\eta2 = .158$
Immersion			$F(1, 30) = 25.854$, $p < .001$, $\eta2 = .463$
Controllability			$F(1, 30) = 50.610$, $p < .001$, $\eta2 = .628$
Intuitiveness			$F(1, 30) = 23.065$, $p < .001$, $\eta2 = .435$

Results

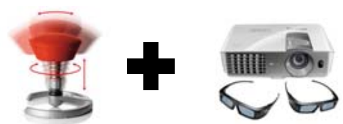
Student's Ideal Design Simulation Preference

40.6% Oculus Rift and NaviChair

37.5% Oculus Rift and joystick

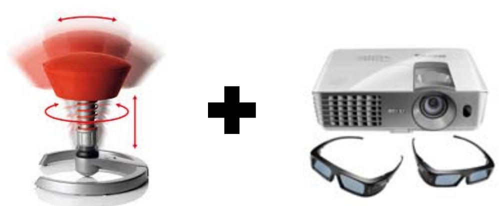


12.5% 3D projection screen and joystick



9.4% 3D projection screen and NaviChair

Architect's Ideal Design Simulation Preference



Explore → Design → **Evaluate**

Exploration

Found that architects believe **IVR representations would be useful** in practice

Described **13 distinct IVR architectural representation usage scenarios**

Discovered an IVR representation interface design differs primarily along two dimensions:

- **Individual** or **Multiple Users**
- **Process** or **Presentation**

Outlined **core system requirements** for an IVR architectural representation interface that can be expanded to fulfill each usage scenario

Design

Designed an IVR architectural representation interface according to requirements:

- Two visual displays supported: **HMD** and **3D projection screen**
- Embodied velocity control locomotion interface: **NaviChair**
- Conversion and optimization of institutional building project: **Revit to Unity**

Key Findings/Contributions

Evaluation

Compared Oculus Rift HMD and 3D projection screen for measures of **spatial orientation**, **motion sickness**, and **immersion**:

Orientation performance and **immersion ratings** higher with HMD

Motion sickness lower with 3D projection screen

Compared NaviChair and joystick for measures of **spatial orientation**, **motion sickness**, **immersion**, **intuitiveness**, and **controllability**:

Immersion ratings higher with NaviChair

Controllability and intuitiveness ratings better with joystick

Found that SFU students **preferred the Oculus Rift HMD and Swopper Chair** for a design simulation scenario.

Design Guidelines

Minimize Sensory Disconnection
Some users described feeling nausea when turning with the NaviChair

Allow Accessibility for All Heights
Shorter users had difficulty leveraging weight to control the NaviChair

Provide Adjustable Locomotion Sensitivity
Users often found the rate of rotation or translation to be either too high or too low

Support Multiple Control Mappings
A few users expected to rotate when leaning sideways, but instead translated

Give Users a Sense of Safety
Some users conveyed feeling unsafe on the convex Swopper seat, particularly with the HMD

Limitations

Only 7 interview participants and 2 focus groups, **possible that more scenarios and requirements could be uncovered**

Interviews and focus groups evaluated informally by a single researcher, resulting in **lowered validity and reliability of findings**

The experimental evaluation involved students, so **findings may not be generalizable to architects and clients**

All but one of our participants had used joysticks previously, so **ratings of controllability and intuitiveness for the joystick may be inflated**

The degrees of freedom of the joystick (2DOF) with the NaviChair (3DOF) differ, so **findings may be influenced by different degrees of freedom**

The lowest height setting of the NaviChair was too tall for some users, so **user height have made controlling the NaviChair more difficult**

Future Work

Respond to NaviChair design guidelines:

- 360 Rotation support for HMD
- Support shorter users
- Sensitivity adjustment
- Toggle mapping control
- Concave seat or backrest

Explore more options:

- Muvman chair modification
- Whiteboard collaboration scenarios
- Distance collaboration scenarios

References

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