FaceDisplay: Towards Asymmetric Multi-User Interaction for Nomadic Virtual Reality

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Motivation

- Virtual reality (VR) using head-mounted displays (HMDs) is primarily a single user experience where typically only the person wearing the HMD can see and interact with the experience.
- People around the HMD user are reduced to just observers
- FaceDisplay (pictured left) enables non-HMD users to visualize and interact with the HMD user
- Explore design considerations for asymmetric, co-located VR applications

Outline

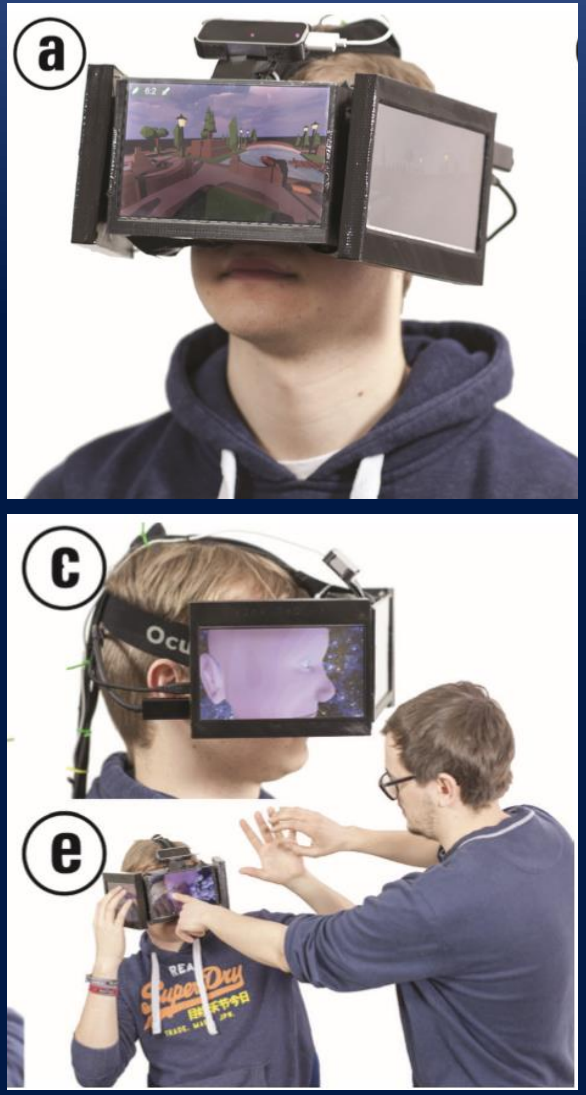
- Motivation
- Research Questions
- Main Contributions
- FaceSpace Implementation
- Evaluation
  - Study Design
  - Results
- Discussion

Research Questions

- What social and interaction dynamics arise from using FaceDisplay
- How to people perceive the physical interaction as the HMD user and non-HMD user
- How to the roles (HMD/non-HMD user) and interaction (touch/gesture) impact enjoyment, presence, and emotional states.

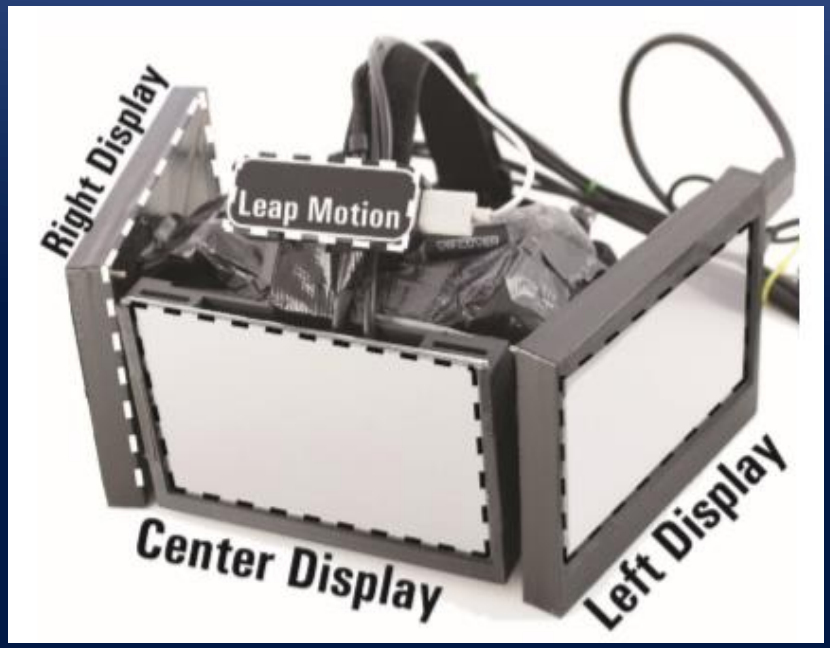
Main Contributions

- FaceDisplay as a vision of mobile VR for both the wearer and surrounding people
- Prototype of a mobile VR setup and example applications
  - FruitSlicer, SpaceFace, Conductor
- Exploratory evaluation of FaceDisplay



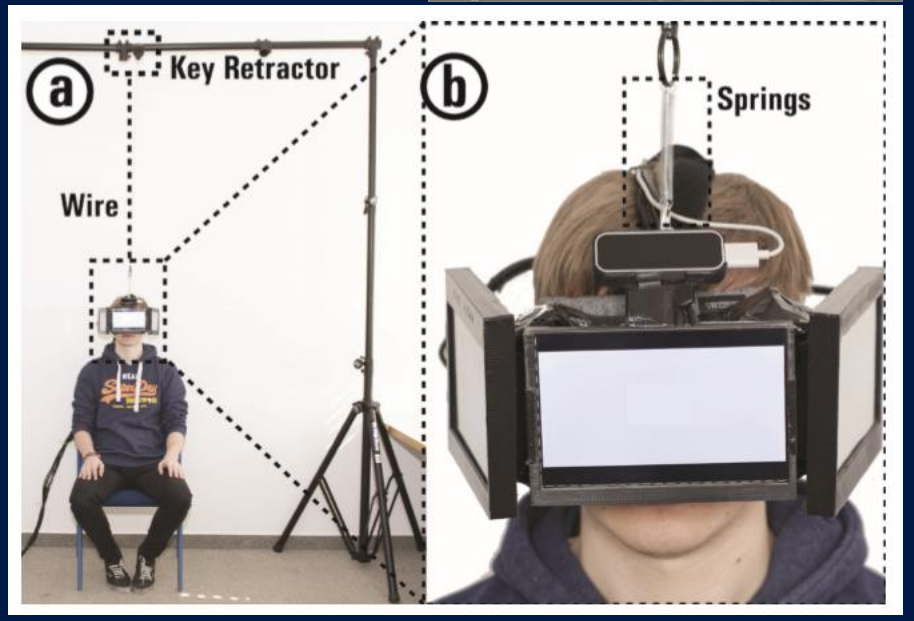
FaceDisplay

- Oculus Rift DK2
  - 5.7” 1920x1080 display
  - 960x1080 per eye
- Three touchscreen displays
  - 7” 1280x800 (front)
  - 7” 1024x600 (left/right)
  - Used by both HMD and non-HMD users
- Leap Motion
  - Hand gestures of non-HMD user



FaceDisplay

- HMD attached to a ceiling rig similar to Ivan Sutherland's Sword of Damocles VR setup (pictured top)
  - Widely considered the world's first VR HMD (1968)
- Retractable keyholder and springs
- Reduce the weight of the HMD, but still allow user to move their head around



Applications

- Fruit Slicer
  - Similar to Fruit Ninja
  - HMD user: First person view
  - Use touch screen to slice fruits, ignore bombs
  - Non-HMD user: Sees VR world a distance from HMD player
    - Uses touch screen to spawn fruit depending on which of three screens is tapped
- Space Face
  - HMD user: First person view
    - Touch/hold on screen to patch cracks in visor
  - Non-HMD user: Sees into HMD users face in helmet
    - Tap screen to create cracks in visor
- Conductor
  - Similar to Guitar Hero
  - HMD user taps screen in time with music track (But can't see track)
  - Non-HMD user can see track and uses hand gestures (visible to HMD) to guide HMD user

User Study Overview

- 16 participants (4 female)
  - The average age was 27.94 years (SD=2.94)
  - Participants reported an average experience with VR devices of 17.6 months (range: 1 to 48)
  - Self-reported interest in VR technology of 6.3 (SD=0.7) on a 7-point Likert scale
- Study performed in pairs
- Independent variables (IV)
  - Role (HMD/non-HMD)
  - Experiences (SpaceFace – touch, Conductor – gesture)
- Repeated measures factorial design
  - Each participant ran each experience in both roles
  - 2 experiences * 2 roles = 4 total runs per participant pair
  - 5 minutes per run -> 20 minutes total

Conceptualization

- Research Questions
  - What social and interaction dynamics arise from FaceDisplay
  - How do people perceive the physical interaction and HMD user and Non-HMD user
  - How do the roles (HMD/non-HMD user) and interaction (touch/gesture) impact **enjoyment**, **presence**, and **emotional** state.
- Qualitative Analysis
  - Coded video of users interacting with FaceDisplay
- Quantitative Analysis (Author: IV?)
  - Enjoyment
  - Presence
  - Emotional State

Operationalization

- Quantitative Analysis
  - **Enjoyment: Game Experience Questionnaire (GEQ)**
  - Presence: Slater, Usoh, and Steed (SUS) Questionnaire
  - Emotional State: Self-Assessment Manikin (SAM)

- Game Experience Questionnaire (GEQ)
  - In-game questionnaire of several items (pictured) measured on a scale of 0 to 4.
  - Overall enjoyment
  - Social Interaction/Presence
    - Empathy
    - Negative Feelings
    - Behavioral Involvement

Table 1
Game Engagement Questionnaire (GEQ) items.

1	I lose track of time
2	Things seem to happen automatically
3	I feel different
4	I feel scared
5	The game feels real
6	If someone talks to me, I don't hear them
7	I get wound up
8	Time seems to kind of stand still or stop
9	I feel spaced out
10	I don't answer when someone talks to me
11	I can't tell that I'm getting tired
12	Playing seems automatic
13	My thoughts go fast
14	I lose track of where I am
15	I play without thinking about how to play
16	Playing makes me feel calm
17	I play longer than I meant to
18	I really get into the game
19	I feel like I just can't stop playing

WA IJsselsteijn, YAW De Kort, and K Poels. 2013. The Game Experience Questionnaire: Development of a Self-report Measure to Assess the Psychological Impact of Digital Games. (2013).

Operationalization

- Quantitative Analysis
  - Enjoyment: Game Experience Questionnaire (GEQ)
  - **Presence: Slater, Usoh, and Steed (SUS) Questionnaire**
  - Emotional State: Self-Assessment Manikin (SAM)

- Presence: Slater, Usoh, and Steed (SUS) Questionnaire
  - 1 to 7 scale rating
  - “In the computer generated I had a sense of "being there“”
    - Not at all (1)
    - Very Much (7)
  - “There were times during the experience when the computer generated world became more real or present for me compared to the "real world“”
    - At no time (1)
    - Almost all of the Time (7)
  - “The computer generated world seems to me to be more like…”
    - Something that I saw (1)
    - Somewhere that I visited (7)

Mel Slater, Martin Usoh, and Anthony Steed. 1994. Depth of Presence in Virtual Environments. Presence: Teleoperators &Virtual Environments 3, 2 (1994), 130–144.

Operationalization

- Quantitative Analysis
  - Enjoyment: Game Experience Questionnaire (GEQ)
  - Presence: Slater, Usoh, and Steed (SUS) Questionnaire
  - **Emotional State: Self-Assessment Manikin (SAM)**

- Emotional State: Self-Assessment Manikin (SAM)
  - Non-verbal pictorial assessment to measure:
    - Pleasure
    - Arousal
    - Dominance

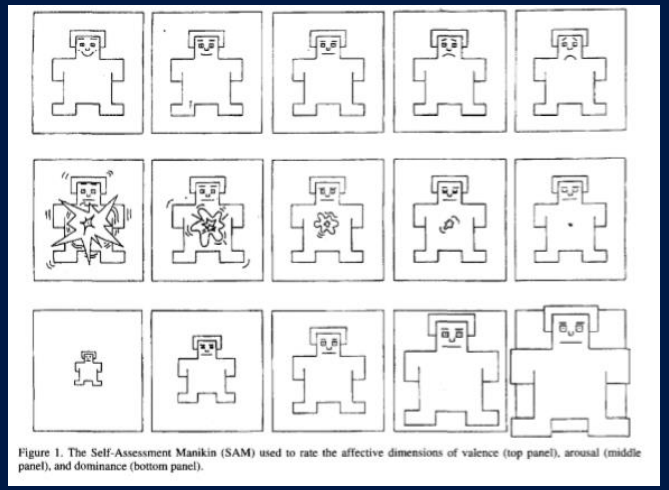


Figure 1. The Self-Assessment Manikin (SAM) used to rate the affective dimensions of valence (top panel), arousal (middle panel), and dominance (bottom panel).

Margaret M Bradley and Peter J Lang. 1994. Measuring Emotion: The Self-assessment Manikin and the Semantic Differential. Journal of behavior therapy and experimental psychiatry 25, 1 (1994), 49–59.

Analysis

- Quantitative Analysis
  - Enjoyment: Game Experience Questionnaire (GEQ)
  - Presence: Slater, Usoh, and Steed (SUS) Questionnaire
  - Emotional State: Self-Assessment Manikin (SAM)

- GEQ and SUS
  - 2x2 (Role x Experience) repeated-measures ANOVA (R-ANOVA) with Bonferroni correction
    - IV: Role (HMD/non-HMD) and Experience (SpaceFace – touch, Conductor – gesture)
    - Each participant performed both experiences in each role (within-subject design)
- SAM and author questions
  - Wilcoxon signed-rank test (within-subject design(

Results

- Enjoyment (In-game GEQ)
  - Several components measured on a scale from 0 to 4
    - Average 2.6 with no significant difference from roles
  - Author's "I enjoyed using FaceDisplay" on a 7-point scale
    - avg. 5
- Social Interaction (Social presence part of GEQ)
  - Three subscales (Empathy, Negative Feelings, Behavioral Involvement)
  - Results:
    - Sig. more empathy with Conductor (M=2.70,SD=0.52) vs SpaceFace (M=2.03,SD=0.75)
      - $F(1,15) = 7.899, p < .05$
    - Sig. more empathy as non-HMD user (M=2.5,SD=0.65) vs HMD user (M=2.25,SD=0.77)
      - $F(1,15) = 6.881, p < .05$
    - Sig. more negative feelings playing SpaceFace (M=2.04,SD=0.95) vs Conductor(M=1.01, SD=0.52)
      - $F(1,15)=41.472, p<.001$
      - Authors: Negative feelings did not impact enjoyment?

Results (2)

- Presence (SUS)
  - Results:
    - Sig. more present as HMD user (M=4.09, SD=1.30) vs non-HMD (M=2.18,SD=1,12)
      - ($F(1, 15) = 38.399$, $p < .001$
    - No sig. difference between experiences
- Emotional State
  - Results:
    - Sig. higher level of dominance (Influence) as non-HMD user (Mdn=6) vs HMD user (Mdn=4) in both experiences
      - SpaceFace ($Z = -2.567$, $p < .01$)
      - Conductor ($Z = -2.939$, $p < .01$)
    - Sig. higher level of arousal (Alertness) playing SpaceFace (Mdn=5.5) vs Conductor (Mdn=4) in both roles
      - HMD User ($Z=-2.811$, $p<.01$)
      - Non-HMD User ($Z=-2.979$, $p<.01$)
    - So sig. diff in valence (Good/bad)

Results (3)

- Discomfort, Agency, Understanding
  - Results:
    - Sig. more discomfort as non-HMD user (Mdn=2) vs HMD user (Mdn=1) in Conductor
      - $Z = -3.219$, $p < .001$
    - Sig. more discomfort in SpaceFace (Mdn=3) than Conductor (Mdn=1) as HMD user
      - $Z = -3.103$, $p < .01$
      - Authors: As expected given nature of game
    - Sig. higher agency as non-HMD user (Mdn=7) than HMD user (Mdn=6) in FaceSpace
    - Sig. higher understanding as non-HMD user (Mdn=6) than HMD user (Mdn=5.5) in FaceSpace

Results (4)

- Qualitative Feedback and Observations
  - SpaceFace had a larger variety of interactions compared to Conductor
    - Both participants were often in constant motion
    - Couples tend to have more intimate interactions - hugging, tickling
    - Non-HMD users would often interacting directly with HMD user actions and less with the screens
    - Non-HMD users would walk around to sneak around HMD user
    - HMD user would use free hand to search or repel non-HMD user
  - Conductor
    - Limited position changes after start
    - Non-HMD user arm fatigue

Discussion

- *a first impression...*: when I'm using an HMD I feel very disoriented from the real world -- the last thing that I would want would be someone poking my face
- I'm skeptical about the "nomadic" part of the title. In the paper, they mention that they had to build a rig to hold up the HMD because it was too heavy.
- The paper discusses the "Interaction Gradient" for FaceDisplay. Is human visual acuity even good enough to be able to make use of the FaceDisplay at the External Device and Observer distances?
- At least their p-values were good!

- On page 7 in the second paragraph under study design, the authors list independent variables of enjoyment along with many additional measures. Would these actually be dependent variables?
- The impact of interaction concept on enjoyment, presence, and emotional state does not seem to be fully explored (stated research question 3). The game content would affect these items, arguably more so than the interaction concept. I think the game content does help emphasize interaction dynamics and perceptions by HMD and non-HMD users, but the impact on interaction seems fuzzy.

- I personally feel the benefits of the artifact do not rule out its limitations (The authors also listed the them in the discussion section). Though comparing it to the mini-me paper this paper did not clearly list the external and internal factors that effect the data and the participant behavior.
- The authors performed a repeated anova for RoleX Experience, so I would assume they considered the intervals to be normally distributed, but the other metrics were not? I am confused as to why the Game Experience Questionnaire was subjected to parametric tests assuming they were intervals also (My understanding, the author does not specify?).

- Why did they implement touch, I wouldn't be comfortable? Why the third game?
- This study is exploring only one style: asymmetric co-located collaboration and they implemented three different games for the same style
- This study did not only rely on questionnaire answers, they also coded the videos