Pseudo-Haptic and Self-Haptic Feedback during VR Text Entry

KOUNALAKI MARIA, IOULIA SIMOU, ANDREAS KOMNINOS

HUMAN-COMPUTER INTERACTION

“We must design for the way people behave, not for how we would wish them to behave.”

- DONALD A. NORMAN, LIVING WITH COMPLEXITY

Defining the problem

Aim:

Efficient and accurate text input methods in VR environment with bare hands

Challenge:

Absence of physical keyboards ⇒ need to provide users with appropriate tactile feedback

Proposal:

- Self-haptics which utilizes the user's own body as a surface to provide tactile feedback compared to pseudo-haptics
- Bimanual input method for VR text entry: highlight keys with one hand & pinch-to-select gesture with second hand

Implementation & Design (1)

Technology & Materials:

- HTC Vive VR headset
- Ultraleap’s Leap Motion Controller (hand tracking)
- Unity game development platform (C#)
- Plugin: Ultraleap Unity API
  - Core
  - Interaction Engine
  - Hand Models

Implementation & Design (2)

Scenes:

- “One handed Interaction” scene – Pseudo-haptics (K2)
- “Two handed Interaction” scene – Self-haptics (K1)

Research Questions:

Text entry speed, error rates, user experience

Keyboard development

- QWERTY layout
- Keyboard Screen: Canvas GameObject with InputField
- UI panel with keys: alphabet letters, space button, backspace button (InteractionBehaviours)

“InteractionBehaviours” components (aka Interaction Objects):

- Enable GameObjects to interact with interaction controllers (Leap Hands)
- Poked, prodded, smacked, grasped, thrown around
- Hovering, contact, grasping callbacks
- “InteractionButton” components: Physics-enabled button with events for “press” and “unpress”

Pseudo-haptics (K2) scene (1)

One hand interaction:

Hover and Press with index finger

Color feedback:

- Keys proximal to the finger tip are highlighted grey
- Successfully Pressed keys turn green

Self-haptics (K1) scene (1)

Two hands interaction:

Hover with R index finger and Pinch with L thumb and index

Self-haptic with Pinch detector:

- Keys proximal to the R finger tip are highlighted grey
- Connect L thumb and index to Click

Experiment Design (1)

- Investigate text entry speed, error rates, user experience
- Three conditions:
  - real mobile keyboard (participant skill baseline), WebTEM online platform
  - two VR applications K1, K2 (counterbalanced order)
- Within-Group Design
- 21 phrases: 3 blocks of 7 random phrases (Vetranen & McKenzie's Memorable Phrase Set, "200 Memorable English Phrases" phrase set)
- 2 questionnaires:
  - Demographic data pre-questionnaire: age, gender, current employment status, English knowledge level, previous VR experience, personal VR ownership, frequency of use, subjective typing skills ratings (Likert scale 1-5)
  - Game Experience Questionnaire (GEQ): Immersion, Flow, Competence, Positive & Negative Affect, Tension, Challenge (5-point intensity scale 1-5)

Experiment Design (2)

Data collected:

- Baseline session: WebTEM online platform (WPM, ER, KSPC, CER, TER etc.)
- VR sessions:
  - Custom code using StreamWriter to capture input streams
  - 2 CSV files "PhraseSessions.csv", "TypingEvents.csv" (ID, timestamps, random phrase, submitted phrase, pressed character etc.)

Procedure:

1. Pre-experiment demographics questionnaire / Arrange date and time
2. Integration & familiarization / Consent form & potential risks / Experiment description
3. WebTEM Baseline sessions
4. VR sessions with small breaks between blocks & user experience questionnaire after each session

Experimental Results (1)

Participants:

- 24 (8 female, 16 male)
- 19-32 years old ($\bar{x}$ =23.16, s=3.646)
- 7 participants with previous experience, 1 owner of VR equipment
- English skills: 5 Intermediate (B2), 3 Advanced (C1), 16 Proficient (C2)
- Mobile Typing skills (1-very bad, 5=very good): $\bar{x}$ =3.52, σ=0.73 (min=2, max=5)
- WebTEM results:
  - WPM $\bar{x}$=33.739, σ=6.519, min=22.198, max=55.115
  - TER $\bar{x}$ =3.170, σ=2.516, min=0.0, max=10.392

In-line with expected performances

Metrics (Dependent Variables):

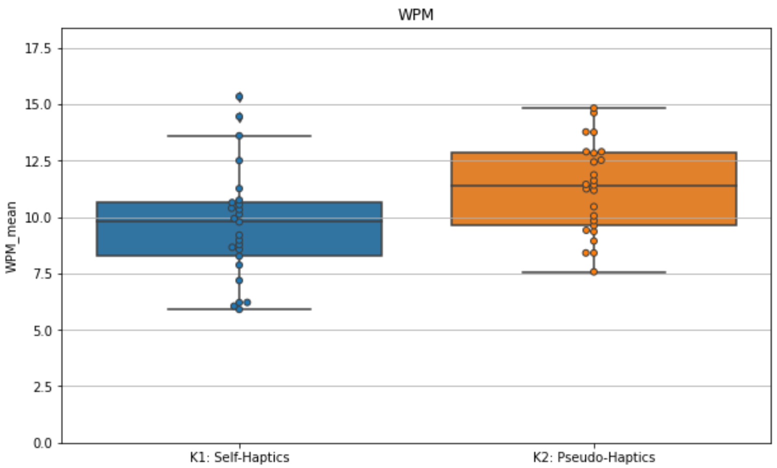
- Text entry speed (WPM, KSPS)
- Error Rates (TER, KSPC)

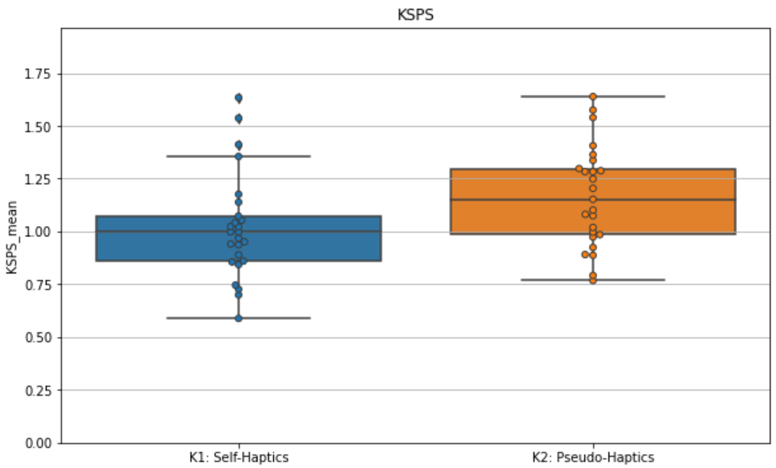
Text Entry Speed (1)

Results:

- K2 faster text entry than K1
- Not very high text entry speed due to:
  - Novelty of experience
  - Leap motion tracking accuracy
  - Targets' size

	K1: Self-haptics	K2: Pseudo-haptics	Statistical test
WPM	9.657 (2.511)	11.249 (2.010)	t= -3.803, p=0.001
KSPS	1.019 (0.252)	1.164 (0.239)	t= -3.893, p=0.001



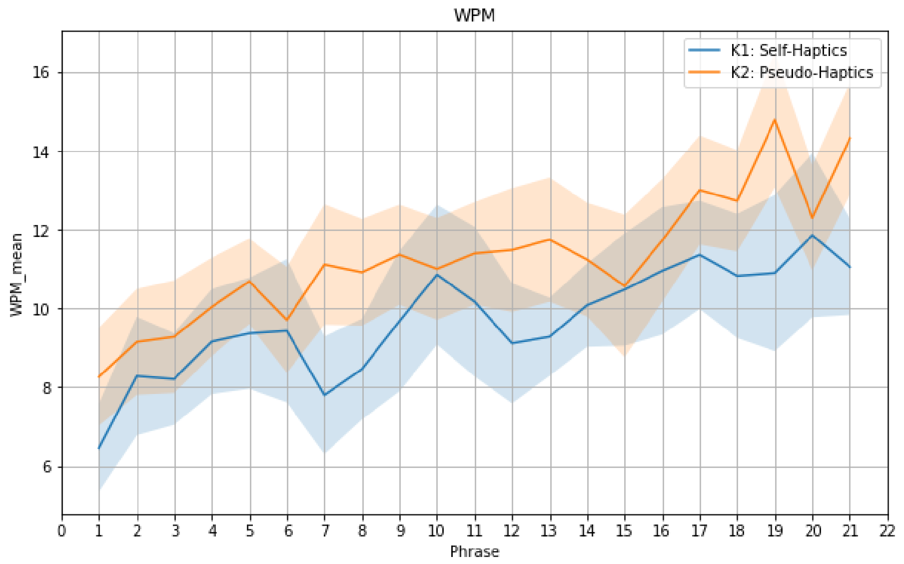


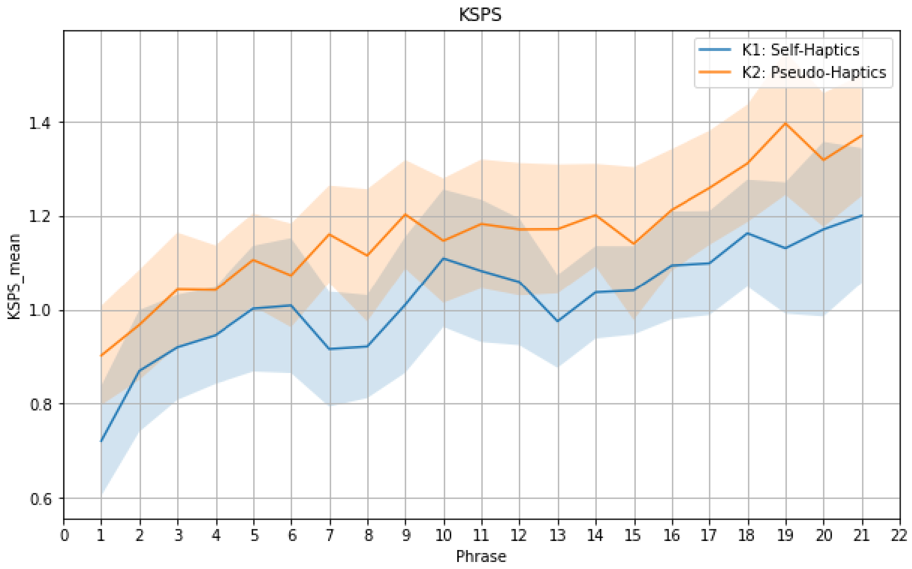
Text Entry Speed (2)

Performance over time:

- Improving WPM & KSPS
- Low entry rates almost doubled

Participants become more proficient with training



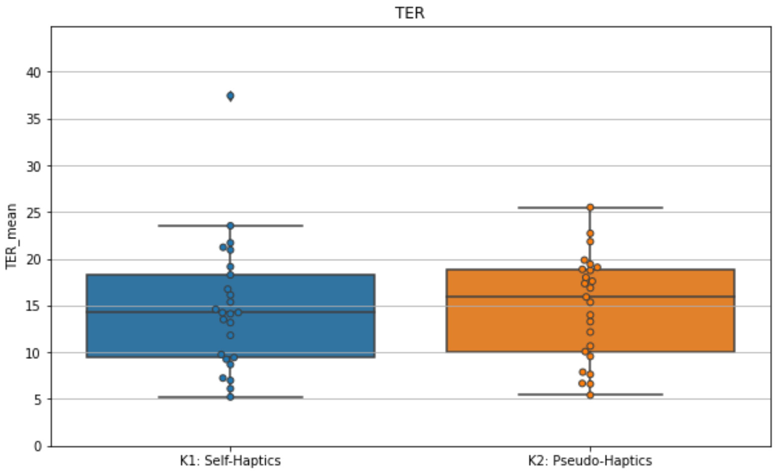


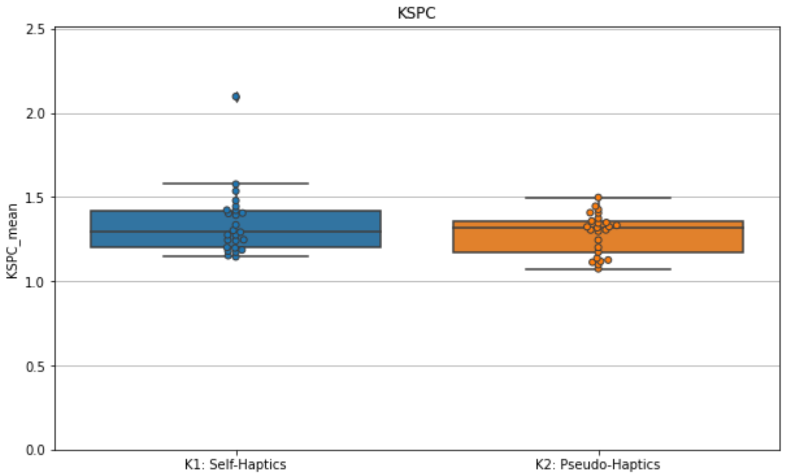
Error Metrics (1)

Results:

- Near identical performance, no statistically significant difference

	K1: Self-haptics	K2: Pseudo-haptics	Statistical test
TER	14.756 (6.993)	14.843 (5.596)	Z=149.0, p=0.731
KSPC	1.344 (0.199)	1.283 (0.121)	Z=109.0, p=0.156



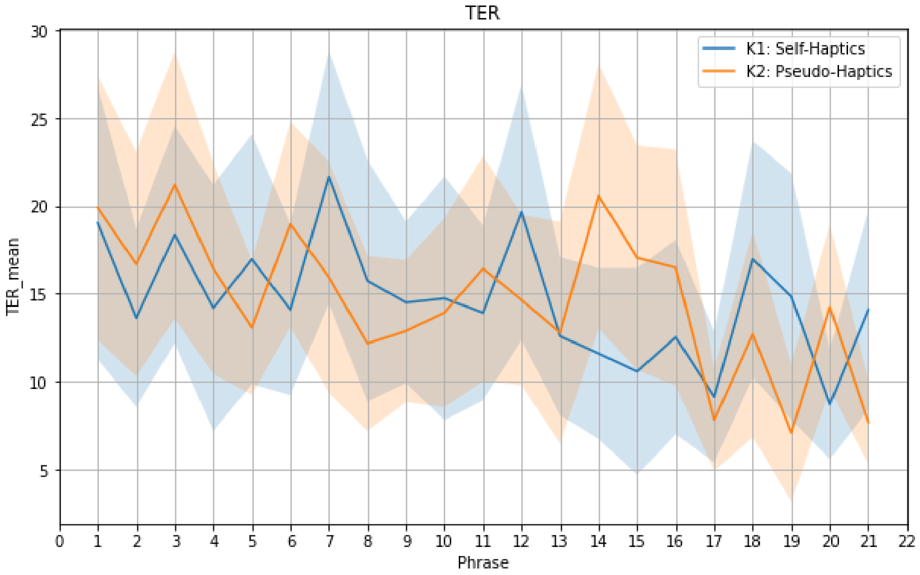


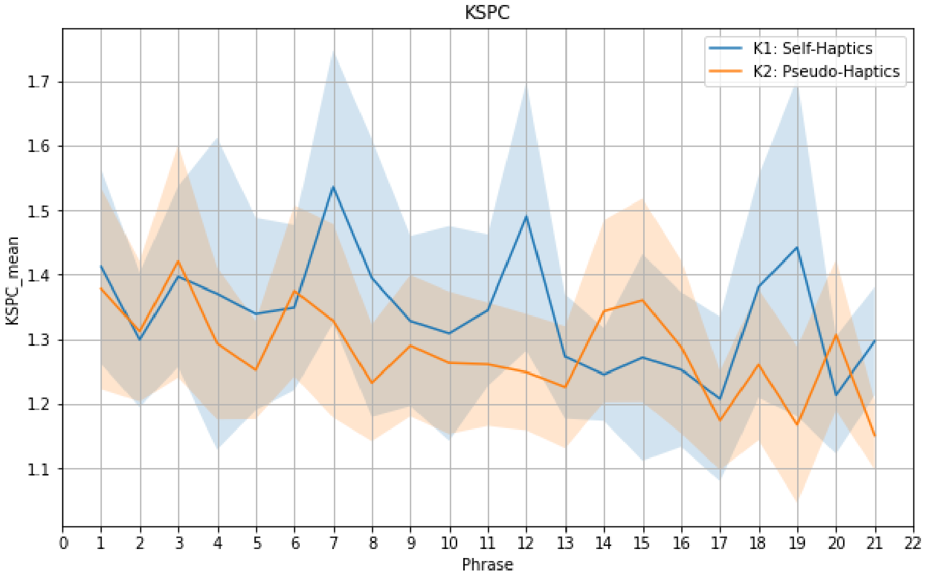
Error Metrics (2)

Performance over time:

- Decreasing numbers
- Less errors over time

Participants become more proficient with training





Subjective Feedback

GEQ component	K1: Self-haptics	K2: Pseudo-haptics	Statistical test
Competence	3.760 (0.698)	3.792 (0.471)	t= -0.278, p=0.784
Sensory & Imaginative Immersion	3.787 (0.700)	3.687 (0.568)	t=0.888, p=0.383
Flow	3.136 (0.840)	2.920 (0.619)	Z=61.0, p=0.019
Tension/Annoyance	1.613 (0.756)	1.667 (0.674)	Z=80.5, p=0.827
Challenge	2.104 (0.545)	2.056 (0.508)	t=0.456, p=0.653
Negative affect	1.810 (0.469)	1.780 (0.588)	Z=112.5, p=0.916
Positive affect	4.056 (0.803)	4.016 (0.565)	t=0.282, p=0.780

⇨ Statistical difference in favour of K1 (self-haptics)

Self-haptics
- Reported to be fun (6)
- Afford good control over input (6)
- Faster typing once mastered (7)
- Problems with hand tracking and pinch recognition (6)
- Tired because of the two hands interaction (8)
- Difficulty synching the select and confirm actions (3)
- Combination of color highlighting and pinch gesture (4)

Pseudo-haptics
- Faster and effortless (6)
- More natural interaction (2)
- Impressed by the experience (8)
- Tricked into having actual touch sensation on fingers (1)
- Tired due to constant back-and-forth movement of arm (7)
- Tracking issues producing erroneous events, less control (10)

Conclusions (1)

'Pseudo-haptics and self-haptics for freehand mid-air text entry in VR', Kim and Xiong:

- Self-haptic vs pseudo-haptic on large QWERTY keyboard (desktop size)
- Typing with both hands

Comparison between performance metrics in our study and Kim and Xiong

	Kim and Xiong		Our study	
Feedback	Self-haptic	Pseudo-haptic	Self-haptic	Pseudo-haptic
WPM	19	19	9.657	11.249
CER	$\bar{x}$ = 9.3%	$\bar{x}$ = 11.4%	$\bar{x}$ = 13.4%	$\bar{x}$ = 13.6%

Conclusions:

- Reasonable difference in entry speed: participants typed with one hand on small area
- Small difference in CER: keyboard small size and hand-tracking issues (different hardware used)

Conclusions (2)

'Pinchtext', Jiang et al.:

- One-handed input on 12-key keyboard
- Lower arm to select keyboard row
- Pinch between thumb and index, middle, ring to select columns
- Conductive tape to detect pinch gesture ≠ bare hands interaction

Comparison between performance metrics in our study and Jiang et al. (Pinchtext)

	Jiang et al.	K1 (our study)	Jiang et al.	K1 (our study)
Phrase range	1 - 10		11 - 20	
WPM	6.10 - 8.13	8.90	8.54 – 9.02	10.59
CKER[a]/CER[b]	8 – 13%[a]	14.46%[b]	8 - 9%[a]	12.06%[b]

Conclusions:

Bimanual method has potential for higher text entry rates with comparable error rates

Future Work

- Address reported hand tracking issues ⇨ enhance user experience and reduce frustrations
- More intuitive and comfortable single-handed interaction ⇨ reduce the need for coordination
- Ergonomic considerations and design adjustments (optimizing hand and arm movements) ⇨ minimize physical strain, reduce fatigue
- Additional visual feedback (color highlighting/cursor) ⇨ enhance understanding & user experience and reduce uncertainty during text entry
- Training & mastery (training resources/tutorials/interactive exercises/feedback mechanisms) ⇨ improve proficiency and speed
- Error reduction cursor as indicator or adding gestures for error correction ⇨ control over input actions, frustration reduction
- Conduct studies with more experienced or familiar participants ⇨ additional feedback on system's usability and performance

Results:

Enhance user satisfaction, increase input efficiency, reduce fatigue, provide seamless and immersive text entry experience

THANK YOU!!!

CLEARED FOR TAKEOFF