A Comparison of Table, Wall, and Midair Mixed Reality Keyboard Locations

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ABSTRACT

Typing on a midair keyboard in mixed reality can be difficult due to the lack of tactile feedback when virtual keys are tapped. Locating the keyboard over a real-world surface offers a potential way to mitigate this issue. We measured user performance and preference when a virtual keyboard was located on a table, on a wall, or in midair. Despite the additional tactile feedback offered by the table and wall locations, we found the midair location had a significantly higher entry rate with a similar error rate compared to the other locations. Participants also preferred the midair location over the other locations.

CCS CONCEPTS

• **Human-centered computing** → **Text input**; **Mixed / augmented reality**.

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1 INTRODUCTION

While mixed reality (MR) is often used for entertainment, we imagine MR will evolve to support day-to-day tasks like writing emails. We believe by 2030, MR headsets will begin to replace cell phones as the primary mobile computing platform. Text input in mixed reality can use an auxiliary input devices (e.g. handheld controllers [2, 10], physical keyboards [8, 12]). But without such devices, input can be challenging. Speech is an option [1, 9], but can present privacy issues and may not work for difficult to predict text (e.g. passwords). While past work has explored physical and tablet keyboards in virtual reality [4, 5, 7], we focus on typing on everyday flat surfaces. While tactile feedback can be provided via wrist or finger devices [6], we explore collision with a real-world surface. Further, we compare different locations with a deterministic (i.e. without auto-correct) full keyboard (i.e. including numbers, symbols, and case). We did this to better understand the role of surface-based tactile feedback for precise typing not amendable to prediction.

2 USER STUDY

We had 18 participants complete three counterbalanced conditions: Midair, Table, and Wall. Participants used a Microsoft MR HoloLens 2 headset while seated at a small table (Figure 1). We placed a QR code paced on the table as a spatial anchor for the virtual keyboard (Figure 2). All conditions provided visual and audio feedback. The Table and Wall conditions also provided tactile feedback by placing the keyboard just above the table or the wall behind the table. The Midair condition placed the keyboard in midair in front of the participant. The midair keyboard was angled slightly up to support a comfortable wrist posture (similar to [3]). We used a full QWERTY keyboard including numbers, symbols, shift, caps lock, and backspace. The keyboards size was approximately 44 cm × 16 cm. The keyboard was deterministic and did not provide auto-correct or word predictions. Participants saw their current text above the keyboard and could correct any errors using backspace. A key was triggered when a participant's index finger entered and exited the top plane of the key.

During the one-hour study, participants completed an initial survey and then performed input in each of the three conditions. Between each condition, participants took a two-minute break and completed a survey about the previous condition. Participants also completed a final survey. At the start of each condition, participants typed a calibration sentence, two practice sentences, and 12 evaluation sentences. The calibration sentence was used to set the keyboard's height above the surface. The calibration only had effect in the Wall and Table conditions, but we retained it in Midair for consistency. We used sentences from the "mem1-5" set from the mobile Enron dataset [11]. Sentences contained upper and lowercase letters, punctuation, and numbers. Participants typed with one hand (whichever they preferred).

We measured entry rate in words per minute (WPM) with a word being five characters including space. We timed from the first key until the next button. Entry rates were 12.2, 9.1, and 7.8 WPM in Midair, Table, and Wall respectively (Figure 3). A repeated measures ANOVA found this difference was significant ($F_{2,34} = 31.3, p < 0.001$). Bonferroni corrected post-hoc tests found Midair > Table ($p < 0.001$), Midair > Wall ($p < 0.001$), and Table ≈ Wall ($p = 0.12$).

We measured error rate using character error rate (CER). CER is the number of character insertions, substitutions, and deletions required to change the entered text to the reference divided by the number of characters in the reference multiplied by 100. The CER was 0.95, 0.98, and 0.65 in Midair, Table, and Wall respectively. This difference was not significant ($F_{2,34} = 0.89, p = 0.42$). While participants' final error rate was low, we observed frequent use of backspace. We measured the number of backspaces typed per

Figure 1: The testing location.

Figure 2: The TABLE condition viewed through the HoloLens. The virtual keyboard appears just above the physical table.

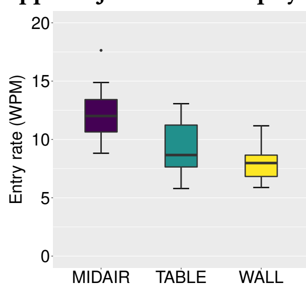

Figure 3: Entry rates in the study.

output character. Participants used backspace somewhat frequently at 0.12 for MIDAIR, 0.16 for TABLE, and 0.13 for WALL. This difference was not significant ($F_{2,34} = 1.73, p = 0.19$).

3 DISCUSSION AND CONCLUSIONS

We found MIDAIR had the highest WPM making it the quickest keyboard to type on. Participants achieved a low final error rate in all conditions, though without auto-correct, our keyboard required moderate use of backspace. In the final survey, 13 participants preferred MIDAIR. The second most preferred condition, by five people, was TABLE. We observed, and open feedback corroborated, key triggering was less reliable for keyboards located near a surface (in particular the table). This could explain the higher performance of MIDAIR. Further work is needed to investigate the cause — it could, for example, be a limitation of the egocentric cameras, the hand tracking models, or our calibration procedure.

In conclusion, our study found that using a HoloLens v2 device, a midair keyboard allowed faster input and was more preferred by users than a keyboard located either horizontally just above a table or vertically just in front of a wall. At least currently, we found our keyboard had difficulty always detecting when a user tapped on a key located right above a physical surface. An interesting avenue for future research would be to use auxiliary sensors (e.g. a microphone) to detect taps instead of, or in addition to, using finger collision with the keys.

4 AUTHOR BIOGRAPHIES

Joshua Reynolds. Joshua Reynolds is a fourth-year undergraduate student at Michigan Technological University. He is currently working towards his B.S. in software engineering. He has been an undergraduate research assistant on this project since the spring of 2021. He is also a member of the Michigan Tech Rowing Club.

Scott Kuhl. Scott Kuhl is an Associate Professor at Michigan Technological University. His research interests include computer graphics, immersive virtual environments, and human spatial perception. He is particularly interested in finding ways to make virtual reality devices more useful for a variety of applications.

Keith Vertanen. Keith Vertanen is an Associate Professor at Michigan Technological University. He specializes in designing intelligent interactive systems that leverage uncertain input technologies. This includes input via speech, on touchscreens, in midair, and via eye-gaze. A particular focus of his research is on systems that enhance the capabilities of users with permanent or situationally-induced disabilities.

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