

Exploring the Display Patterns of Object-Centered User Interface in Head-Worn Mixed Reality Environment

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Figure 1: Three display patterns of Object-Centered UI in head-worn MR environment: (a): Always-Displayed UI, in which virtual UIs are always visible; (b): Glance-Single UI, in which the default hidden UIs will appear one-to-one according to the user's line of sight; (c): Glance-Group UI, in which the default hidden UIs will appear in groups according to the user's line of sight.

ABSTRACT

Object-centered user interface (UI), which UI displayed around real-world objects provides convenience for users to interact with real objects in head-worn Mixed Reality (MR) environment. However, it remains unclear how to design the object-centered UI to reduce the interference of always displayed UI. In this research, we designed two display patterns of object-centered UI and compared them with the basic object-centered UI without any display patterns. Our results demonstrate the trade-offs among the three UIs and collect user preference. Both display patterns can provide better support for users while reducing the occlusion and interference of the UI.

Index Terms: Human-centered computing—Mixed / augmented reality; Human-centered computing—User interface design

1 INTRODUCTION

Mixed reality head-worn displays (MR HWDs) have the potential to support users' everyday use in the future. Object-centered UI [1], where virtual UI in MR environment is displayed next to its corresponding interactable object, provide the user with a better connection to the real-world and reduce the obstruction of the user's view by the interface. However, although object-centered UI is a promising design solution, its always-displayed interface still suffers from occlusion problems which requires a more suitable solution to optimize the design.

Inspired by the Glanceable AR [2] and the techniques for rapid activation [3], we designed two display patterns of object-centered UI using eye-tracking technology, in which the UIs are hidden when not activated. We evaluated the UIs using both display patterns as well as a basic object-centered UI without any display patterns in a simulated real-use indoor environment. The results show that the two display patterns can provide better support for

users in performing tasks with a clearer view.

2 OBJECT-CENTERED UI DISPLAY PATTERNS

For the object-centered UI to be accepted better, it needs to be as unobtrusive as possible to the user's everyday behaviour, while supporting a more lightweight and natural way of interaction. Based on the basic design of object-centered UI, we designed two UI display patterns based on eye-tracking technology: Glance-Single UI and Glance-Group UI, where all virtual UI are hidden by default and the user needs to make the interface appear by glancing at the corresponding object.

The display of the Glance-Single UI (GS) is one-to-one with the user's sight target, which means that when the user glances at an object, only the interface corresponding to the object will be displayed (see Fig. 1b and 2b).

The display of the Glance-Group UI (GG) is one-to-many, which means that the UIs of all the interactable objects in a certain area near the target object will appear together with the UI of the target object when the user looks at the target object (see Fig. 1c and 2c).

For the UIs without any display patterns, all the object-centered UIs are always visible whether the user looks at the objects or not, which we call Always-Displayed UI (AD) (see Fig. 1a and 2a).

3 EXPERIMENT

We conducted a user study with 28 participants (14 females) between 19 and 26 years old ($M = 23.61$). Seventeen of them have experience with MR. The experiments were conducted in a 4m x 7m indoor environment simulating a real-world usage scenario, containing eight interactable real-world objects (see Fig. 3).

We used a within-subjects design. Latin square counterbalancing was applied to the order of the conditions. Participants were asked to sit at a desk wearing HoloLens 2 and perform the tasks using each of the three UIs. Each set of experimental tasks consisted of four subtasks, each of which required participants to find the specified object, trigger the corresponding UI and complete the interaction that triggers the specified icons according to the instructions on the question paper on the table, and to complete a text fill-in-the-blank question from the paper in a handwritten manner. The solutions will be displayed in the MR UI if the participant completes the action correctly according to the instructions. Participants were asked to fill in the blanks correctly

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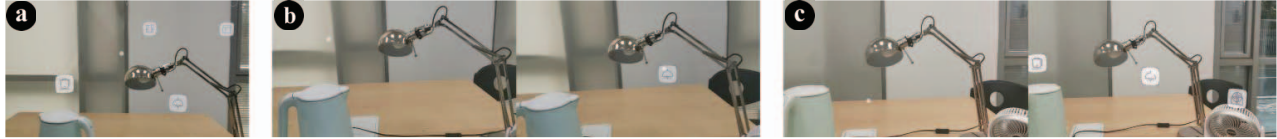


Figure 2: The implementations of (a) Always-Display UI, (b) Glance-Single UI, and (c) Glance-Group UI in head-worn MR environment.

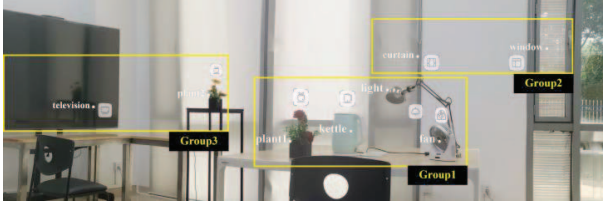


Figure 3: Experimental environment with eight interactable objects.

based on the content of the virtual text.

We collected three sources of time for participants to perform each subtask for finding time (the time it took to find the correct task target), triggering time (the time it took from finding the target to successfully activating its UI), and completion time (the time it took to complete the task) and calculated the total value for each participant in each condition. After each condition, participants were asked to fill out the System Usability Scale (SUS) [4] and NASA TLX workload questionnaire [5], as well as a questionnaire asking about occlusion using a 7-point Likert scale. Finally, we asked participants for their preferences and collected their comments on each interface in the interviews.

4 RESULTS

We used one-way repeated-measures ANOVA (RM-ANOVA) tests on all time data. Shapiro-Wilk tests were applied to test the normality of the data. Friedman tests were applied when data failed the normality tests. For qualitative data gathered from questionnaires and recordings, Wilcoxon signed-rank tests were conducted. We applied Bonferroni corrections for all pair-wise comparisons. We used an α level of 0.05 in all significance tests.

Time. RM-ANOVA yielded significant main effect of UIs on finding time ($F(2,54) = 9.194, p < .001$), triggering time ($F(2,54) = 5.464, p = .007$), and completion time ($F(1.328,35.847) = 5.198, p = .020$). Pairwise comparisons showed that AD ($M = 8.71, SD = 4.40$) led to more time than both GG ($M = 5.79, SD = 1.97$) ($p < .001$) and GS ($M = .68, SD = 2.63$) ($p = .016$) for finding time, GS led to more time than GG ($p = .006$) for triggering time, GG ($M = 299.89, SD = 56.80$) led to less time than AD ($M = 339.04, SD = 63.34$) ($p = .048$) for completion time.

Overall usability. There is no significant difference in SUS scores among GG ($M=73.93, SD=12.48$), AD ($M=73.39, SD=13.56$) and GS ($M=72.59, SD=13.82$), distributed more or less around the “good” rating [6].

Workload. Pairwise comparisons showed that GS yielded a higher level of effort (GS-AD: $p < .001$; GS-GG: $p = .011$) and frustration (GS-AD: $p = .018$; GS-GG: $p = .009$) than AD and GG. GG yielded a higher level of effort than that AD ($p = .049$).

Visual occlusion. Friedman test yielded main effects of UI on the ratings for the occlusion of virtual information and real-world information ($p < .001$). For the unobstructed view performance of browsing virtual content, GS ($M = 5.89, SD = .31$) was rated higher than AD ($M = 4.00, SD = 1.00$) ($p < .001$) and GG ($M = 4.00, SD = .93$) ($p < .001$). For the unobstructed view performance of browsing real-world content, GS ($M = 6.00, SD = 1.07$) was rated higher than AD ($M = 4.75, SD = .43$) ($p < .001$) and GG ($M = 5.50, SD = .50$) ($p < .001$), and GG was rated higher than AD ($p = .023$).

User preferences and Comments. Sixteen of the 28 participants (57.1%) preferred GG, 9 (32.1%) preferred GS, and 3 (10.7%) preferred AD. Participants praised AD for being *distinct, convenient* and *dependable*. But participants disliked it for being *complicated, interferential* and *obstructive*. GS was praised for being *specific, unobstructive* and *comfortable*, but participants commented it was *slow* and they felt *uncertain* when using GS as they worry about *whether the user interface will be presented*. As for GG, participants praised it for being *controllable, efficient* and *organized*. They agreed that GG is a good transition between AD and GS, covering the advantages and neutralizing the disadvantages between the two UIs, which is a more moderate choice.

5 DISCUSSION

Although some participants indicated their preference to use AD in their day-to-day life for extended periods of time, their task performance and comments as well as our own experience lead us to believe that AD would not be the ideal UI for long-term use because the virtual information which is always present can cause many distractions to users. Although the effort and frustration of using GS is higher than that of the other two UIs, we believe the importance of GS will become more significant as technology develops. In general, our results show the different benefits and limitations of using GG versus GS. In case of different application scenarios, different object-centered UI display patterns can be chosen to better meet the needs of users.

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