Press the red button: A user study comparing notification placement with augmented and non-augmented tasks in AR

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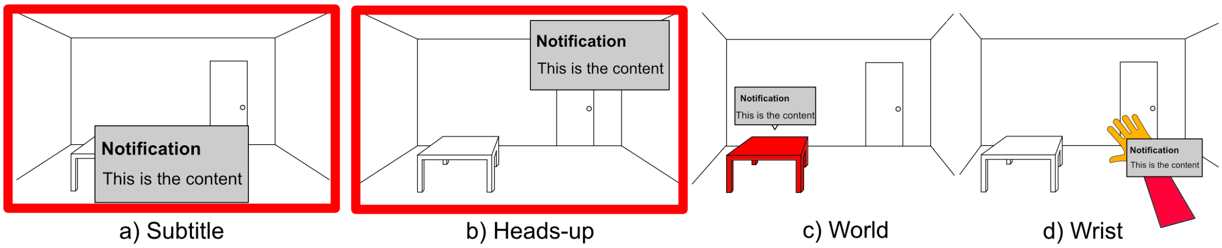

Figure 1: Different notification placements (location is illustrated by the red color, a) and b) are presented in screen space)

Abstract

Visual notifications are omnipresent in applications ranging from smart phones to Virtual Reality (VR) and Augmented Reality (AR) systems. However notifications can cause disruptive effects on task performance and different notification placements have been shown to have an influence on response times, as well as e.g. on user perceived intrusiveness and disruptiveness. We investigated the effects and impacts of four visual notification types in AR environments where a card game task was performed in AR or the real world. In a user study, we interrupted the execution of the main task with one of the AR notification types.

Index Terms: Human-centered computing—User studies
Human-centered computing—Mixed / augmented reality

1 Introduction & Related Work

Visual notifications in Augmented Reality (AR) can be employed to draw a user's attention away from their current main task, towards specific, potentially important events. Nevertheless, interruptions have disruptive effects on the user's task performance and lead to a higher memory load of users at the time of interruption [1]. Orlosky et al. [3] have shown that the use of a head-mounted display for notification delivery can lead to increased spatial awareness with minimal performance impact over the use of a smartphone. In Virtual Reality (VR), presentation and placement of notifications have also been shown to influence response time, noticeability, distraction and intrusiveness [4]. They concluded that there was not a preferred notification placement for all contexts, so position should depend on task and context. Also researching notifications in VR, Ghosh et al. [2] explored interruptions and notifications in VR with several modalities like haptics and audio and derived design guidelines based on their findings.

In this work, we focus on the perception and notability of four different AR-based notifications displayed either during a real world only or an AR-based task: subtitle, heads-up, world space, and user wrist. The main task consists of a card game known as *Memory*, where users have to find matching pairs of cards that are initially laid out face down on a surface. In the real world condition, no virtual content besides the visual notifications is presented to the user. In the AR condition, the card game itself is performed in AR.

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2 Experiment

We conducted an experiment to examine if the position of a notification could affect primary and secondary task performance and if the perception of the notification changes depending on its location. Participants were instructed to play a card game (primary task), during which they received notifications on an optical-see through AR headset, the Microsoft Hololens 2, to which they had to respond to (secondary task). We deployed four different notification PLACEMENTS in an AR-environment with two different TASK scenarios. This resulted in a mixed group design with two independent variables. The notification PLACEMENTS consisted of a notification in the (1) top right *(heads-up-display)*, (2) bottom middle *(subtitle)* portion of the AR headset display, (3) projected on the *wrist*, and (4) situated above the TASK in the *world*. The participants were exposed to all notification types during the experiment.
Cards were either physical or virtual, depending on the TASK, allowing a comparison of whether more virtual content influences notification perception. The TASK for the experiment was a memory card game, as a sustained attention task was chosen for the experiment. Because this game requires a lot of recall ability, intrusive interruptions should have a large impact on the performance.
Participants were given three card decks spread out face-down in a five by six grid each. Two cards had to be flipped and discarded if they matched or else returned face-down. This was repeated until all cards of a deck had been discarded, and then the participant had to move on to the next deck. Users playing with the digital cards could use their right index finger to tap on a card to flip it. Discarding or flipping face down was handled automatically.

While playing the memory game, notifications with different PLACEMENTS were shown to the participants. Each experiment run lasted eight minutes and the notifications appeared every 50 seconds resulting in a total of nine notifications per run. Every notification contained an instruction to press a certain button on a game controller located in the room, which the participant needed to perform. We measured the amount of correctly pressed buttons, missed notifications, reaction time, correct card matches, usability

(SUS questionnaire), task load (NASA-TLX) and perception of notifications [2].

2.1 Notification Design

All notifications had a rectangular form, mimicking the alerts most commonly seen on mobile and desktop operating systems. To ensure high legibility of the text, a dark gray background was chosen, along with white text color, in line with design recommendations by Microsoft.

The heads-up notification is fixed at the top-right border of the display area.
Subtitle notifications are placed at the bottom-center border of the display area.
Both *Subtitle* and *Heads-up* notifications are displayed at a distance of one meter away from the user, in accordance with the comfort guidelines by Microsoft and move with the users head.
Wrist notifications are positioned at the user's right wrist, inspired by notifications that a user wearing a smartwatch might receive.
The world notifications were placed on the top edge of the card deck, whichever the user is currently closest to.

3 Results

37 participants (11m, 26f) were recruited from a pool of university students. Age ranged from 19 to 30 years (M = 22.15, SD = 2.3). Results mentioned here were all statistically significant ($p < .05$).
Wrist produced the best and also the worst score regarding the correctly pressed buttons, depending on TASK. With the AR cards, *Wrist* produced significantly more correct button presses than *Heads-up* or *World* and less missed notifications than *World*. But in the real card TASK, correct button presses, missed notifications and noticeability were all worse than *Subtitle* and reaction time was worse than all other. PLACEMENTS. This can be explained by the fact that with the real cards it was possible to perform the TASK without their hands being in the field of view of the device, causing the notifications to not appear.
World was better in reaction time in the AR TASK than any other and better in the real cards as *Wrist*. They were also better in correct card matches and TLX score than *Heads-up* or *Wrist* across and showed better understandability than *Heads-up* across both TASKS. The decreased reaction time is likely because positioning the notification at their focus might lead to a quicker registration.
Subtitle notifications had higher correct button presses and reaction time than *Wrist* with real cards and scored higher in the SUS than *Heads-up*. They were also evaluated as having a higher understandability as *Heads-up* and better noticeability than *Heads-up* and *Wrist*, regardless of TASK. The results suggest that *Subtitle* notifications were relatively robust, providing consistent results in all measurements. Comparing ***Heads-up*** and *Subtitle* notifications, we found that *Heads-up* did not perform better than *Subtitle* in any of the measurements, while also performing worse in several categories.
At the end of the experiment, participants were asked to rank the PLACEMENT by preference. Across both TASK conditions, *World* notifications were ranked as the best, *Subtitle* as second best, with *Heads-up* being the least favorable.

4 Discussion & Conclusion

Based on the results we propose following recommendations for notification placement in AR:
(1) Use Wrist notifications for high-AR-content scenarios.
(2) Use World notifications if known where the user is looking.
(3) Use Subtitle notifications for universally robust notifications.
In this experiment we compared four different notification placements (*heads-up*, *subtitle*, *world*, *wrist*) in AR while performing one of two card gaming tasks containing physical playing cards with no additional AR content except for notifications *real cards*), or virtual playing cards (*AR-cards*. We found that using notifications located on the *Wrist* should take into account how much interactivity or other content is present in the AR environment. Also when using head-stabilized notification in the user's periphery, bottom-center position should be used over top-right placement. The highest number of correct reactions to a notification, was present with *Wrist* notifications but only with a high amount virtual content in the environment. The quickest response to notifications was found with *World* notifications. Taking the results into account, we constructed design recommendations for notifications in AR.

Table 1: Descriptive statistics; $N = 37$, real cards $n = 18$, AR cards $n = 19$. Values are $M(SD)$. HU = Heads-up

Measure	Scale	HU	Subtitle	World	Wrist
Correct Button (0-9)	Real Cards	6.89 (2.54)	7.89 (2.27)	7.11 (2.03)	5.39 (3.70)
	AR Cards	6.68 (2.79)	7.84 (2.01)	6.47 (2.44)	8.37 (1.67)
Missed Notifications (0-9)	Real Cards	1.94 (2.58)	0.944 (2.29)	1.78 (2.02)	3.61 (3.70)
	AR Cards	2.05 (2.72)	1.0 (1.92)	2.47 (2.29)	0.579 (1.68)
Reaction (in s)	Real Cards	6.54 (0.92)	6.13 (0.84)	5.95 (0.56)	8.69 (1.88)
	AR Cards	7.3 (1.72)	6.89 (1.65)	6.01 (1.08)	7.8 (1.75)
SUS (0 - 100)	Real Cards	67.2 (16.0)	75.1 (13.0)	71.7 (14.2)	70.3 (14.3)
	AR Cards	62.5 (23.9)	70.6 (18.2)	70.1 (18.4)	68.4 (21.2)
NASA TLX (0-100)	Real Cards	34.7 (15.5)	34.3 (14.4)	33.6 (14.7)	38.9 (16.4)
	AR Cards	46.9 (19.7)	40.0 (18.7)	38.1 (16.8)	43.2 (15.2)
Noticeability (1-7)	Real Cards	4.32 (1.89)	5.68 (1.42)	5.26 (1.79)	4.21 (1.9)
	AR Cards	4.45 (2.21)	5.45 (1.73)	4.35 (1.93)	4.75 (1.62)
Understand-ability (1-7)	Real Cards	5.21 (2.07)	6.42 (0.97)	6.26 (1.05)	4.95 (2.46)
	AR Cards	4.90 (2.10)	5.80 (1.80)	6.20 (0.95)	6.05 (1.50)

Acknowledgments

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