Five-day research-in-the-wild observation of notifications on smartglasses: A double edged sword

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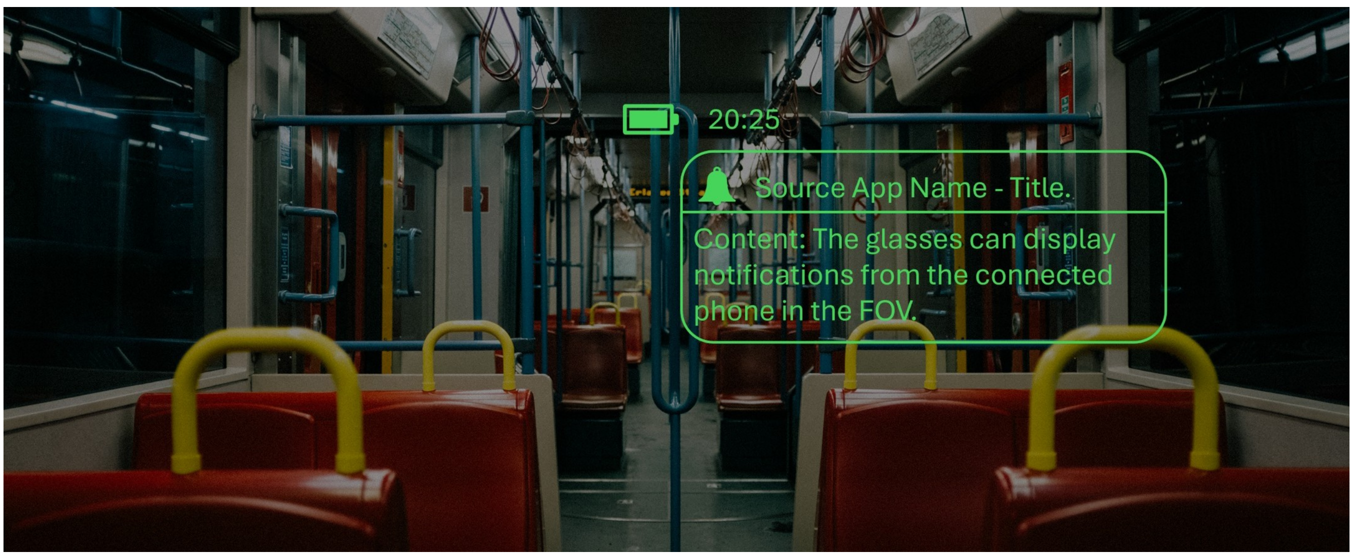

Figure 1: Mockup view of a notification the smartglasses.

Abstract

Notifications are a fundamental aspect of daily computing, whether on desktops, laptops, smartphones, or smartwatches. On average, adults receive around 200 notifications per day—approximately one every five minutes during waking hours. As Extended Reality (XR) headsets advance, they may become the primary medium for digital interactions, making notification management a crucial factor in their usability. While notifications are known to be disruptive on smartphones, their impact could be even more pronounced on head-worn devices. To investigate this, we conducted an exploratory five-day study with eight participants wearing display-equipped smartglasses that delivered notifications from their smartphones. Participants used the glasses throughout their day for at least 2 hours receiving on average 62% of all notifications on the glasses, submitted daily journal entries, and participated in post-study interviews. We also logged notification sources and timestamps throughout the study. Our findings reveal both practical advantages and significant challenges of head-worn notification delivery. While participants appreciated the convenience and immediacy of glanceable alerts, concerns about privacy, social acceptability, and distraction emerged as key barriers to adoption.

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CCS Concepts

• **Human-centered computing** → **Field studies**; *Ubiquitous and mobile devices*; **Mixed / augmented reality**.

Keywords

augmented reality, notifications, smartglasses, user research

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1 Introduction

Digital notifications will continue to play a key role in our daily lives, as their usefulness outweighs many downsides they might have, such as attentional costs [22, 36]. As smartglasses (e.g., Meta Ray Ban [33]) and augmented reality (AR) head-mounted displays (HMDs) are gaining in popularity, it is critical to understand how to design notifications, thinking of a future where everyone is using AR displays alongside or even replacing current computing devices. Currently, most notifications users receive are personal messages or emails [37]. This makes notifications something inherently personal since they directly relate to the user. Pielot and Rello [36] showed that not receiving notifications made participants anxious that they would miss important updates, showing that one of the essential factors behind notifications is that they relate to the user personally. This relation is complicated to replicate in a lab environment, as their controlled nature makes it challenging to send personal notifications to the participants that could be important to them at that exact moment. The context of the current task also plays an essential part in notification delivery. In controlled laboratory experiments about notifications, participants receive specific notifications in a specific context, that typically does not relate to them personally. However, in their daily lives, notifications are delivered throughout the day, with possibly dozens of different usage scenarios. Also, in laboratory settings, the exposure to the stimulus is limited, as most experiments last only up to an hour or two. To gain a better understanding of notifications on smartglasses, we conducted an exploratory "in-the-wild" experiment [42], where participants used a pair of smartglasses throughout their day for five days in their daily life while receiving visual notifications on it. To the best of our knowledge at the time of writing, this work is the first time personal notifications on smartglasses have been explored, especially over a longer period. Our main contributions in this work are the following:

- Insights on notification delivery using HMDs in a five day in-the-wild study.
- Challenges with the long term use of HMDs in daily use.
- An overview of the frequency and types of current mobile notifications.
- Suggestions on how to improve future HMD notification design.

2 Related Work

2.1 Notifications

Research indicates that notifications can negatively impact users, even when they do not engage with them. A study by Stothart et al. [45] demonstrated that participants who received phone calls or texts during a sustained attention task made more errors, highlighting the disruptive nature of notifications on cognitive performance. To explore the long-term effects of notifications, Kushlev et al. [25] conducted a study with 221 participants, assigning them to either maximize or minimize phone interruptions over two weeks. The findings revealed that those who experienced more interruptions reported higher levels of inattention and hyperactivity, traits associated with attention-deficit/hyperactivity disorder (ADHD), as well as decreased productivity and psychological well-being. Additionally, Warnock et al. [49] examined the modalities of notifications and found that both target and distraction notifications negatively affected task performance, with irrelevant notifications causing even greater error rates. While turning off notifications may seem like a straightforward solution to improve concentration, research suggests that the absence of notifications can lead to anxiety and increased checking behavior, as participants felt disconnected from their social circles and worried about missing important information [22, 36]. Ultimately, these studies indicate that notifications hold value for users, as many participants preferred to receive notifications, even with the associated distractions, rather than miss out on important communications.

2.2 Notifications in AR

Designing effective notifications for AR applications involves considering their placement, as traditional displays differ significantly from see-through display, with contrast. Since it has been shown that phone notifications can disrupt conversational settings [8], Rzayev et al. [43] chose a dialogue setting to investigate the effects of notification position in AR. Their findings suggest that general notifications should be placed on the conversation partner, as that placement was found to be the least intrusive while also having the lowest task load for reading the notification while still participating in the conversation. For more important notifications, placement in the center of the field of view (FOV) showed to be the most urgent, but also the most intrusive. However, participants stated that they would accept the negative impact to ensure receiving important notifications. The majority of both people in the setting expressed that they would prefer notifications on an AR headset, rather than a phone.

Lee et al. [26] studied the position of AR notifications during a walking task. They found that a bottom position in the FOV resulted in a significantly higher noticeability and comprehension for notifications compared to the right and top positions, while also showing lower task load. Notifications in the FOV were also perceived as having higher urgency and were reacted to faster than if notifications were attached to users body, and they therefore recommend using this for high-priority notifications. Similarly, Chua et al. [9] found middle or bottom center position ideal for high noticeability of the notification, and middle or top right ideal for unimportant information, while visual attention is on a different task. Plabst et al. [39, 40] investigated the impact of notification location on task performance and perception in AR sustained attention tasks. They found notifications that were placed in the world close to the task, or the bottom center of the FOV were acknowledged more often and faster and were preferred by users, but that it depends on the context. They also found a list attached to the users body ideal for the display of older notifications that have not been attended yet.

2.3 XR in-the-wild

The previously mentioned research efforts largely focus on exploring different UI methods to display notifications, and not on the subjective experience of receiving notifications on head-worn displays. Smartglasses are not yet commonplace, even though their numbers are increasing, which is why we run into the Collingridge dilemma [10]. The dilemma states that when a technology is not yet widespread, it is easy to control, however, its impact on society cannot be predicted. When a technology is widespread, we know its impact, but we can no longer easily control it. Hofmann et al. [19] identify privacy issues as a major concern people have about these devices in their meta-analysis of applicable literature surrounding smartglasses. Most of these concerns relate to the perceived intrusion of privacy because of cameras mounted on the glasses. With more recent devices like the Meta Ray Ban smartglasses [33], that are almost indistinguishable from normal glasses, these privacy concerns could be amplified since onlookers might not even be aware that the glasses are a piece of technology that could potentially record them [21]. Rauschnabel et al. [41] confirm this in a survey about technology adoption, which found that while all the benefits of smartglasses drive the decision to buy a device like this, the only downside driving the purchase decision is the risk to the privacy of *others*, also called *bystander privacy*. In a second experiment consisting of unstructured interviews, they found that participants weren't concerned with their own privacy as much since they felt they had nothing worth hiding in case of unauthorized access or because a breach of their own privacy would not be as immediate as an onlooker being uncomfortable around smartglasses. They also found that many respondents reported that they had already accepted living in a world where privacy doesn't exist anymore.

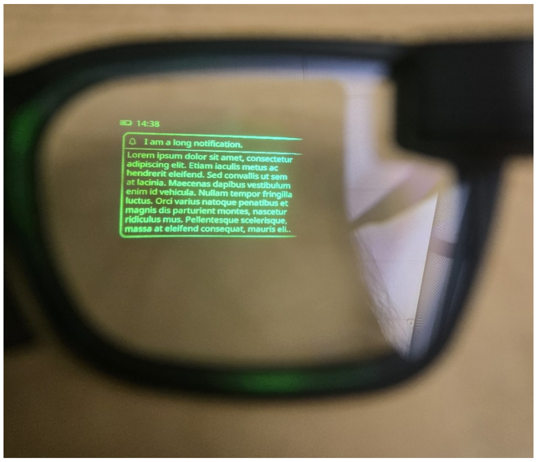
While Rauschnabel et al. [41] findings were on a hypothetical level only, they are supported by McNaney et al. [32] that have conducted five-day field trials, where four patients with Parkinson's disease were asked to wear a pair of Google Glass smartglasses [14] at home and in public to aid with their disease. Three out of four participants reported feeling uncomfortable because of the attention they received from wearing the glasses. This is also supported by an analysis done by Tran et al. [46], in which they analyzed user uploaded videos about wearing AR headsets in day-to-day contexts. They found that many users struggled with the issue of bystander privacy.

Besides this work, there are hardly any studies on longer exposure to XR. Grubert et al. [16] investigated the use of AR in an industrial task, where subjects were exposed to smartglasses for four hours, while completing a search and pick task. The task was completed twice, split across two days, with participants using either AR or no AR on the first or second day. Participants using AR performed significantly better in the task, but half of the participants reported to have experienced visual fatigue. This experiment, however, was also conducted in a laboratory using students and professionals who were not trained in their everyday routine. Looking at virtual reality (VR) exposure, Steinicke et al. [44] exposed one HCI researcher to an immersive virtual environment for 24 hours, with 10-minute breaks after 2 hours of exposure. They found significant issues with simulator sickness and eye strain because of the lower resolution of the device. In a similar but broader study, Biener et al. [4] gave VR headsets to their participants, with a virtual work environment that would resemble a normal desktop environment. They were asked to complete a five-day, eight-hour workweek in this VR environment instead of their usual desks with monitors. They then compared results between the participants who received headsets and participants who continued to work in a physical environment. They found that the use of VR led to severe simulator sickness symptoms and below-average usability ratings compared to the almost identical but physical work environment. Two of their 16 participants had to drop out because of severe nausea and migraine. Looking specifically at notifications in AR, Lucero et al. [30] studied AR notifications and a dedicated attendance device in an urban navigation task. They employed a minimal user interface and a discrete thumb touchpad device for controlling notifications, where butterflies would fly across the display indicating a new notification. Their findings indicated that participants faced minimal difficulties in managing notifications while being exposed to potential hazards in an urban environment. Lu et al. [27, 28] investigated glanceable interfaces for AR devices in-the-wild, where users could access information like emails, weather reports or calendar events among others. The system featured notifications in the form of an icon in the top of the FOV, suggesting to the user that they should open the corresponding application. Participants were asked to complete several 30-minute sessions with the device, after each of which they created a diary entry detailing their experience. Their work shows that AR can be beneficial in day to day acquisition of information without being too distracting.

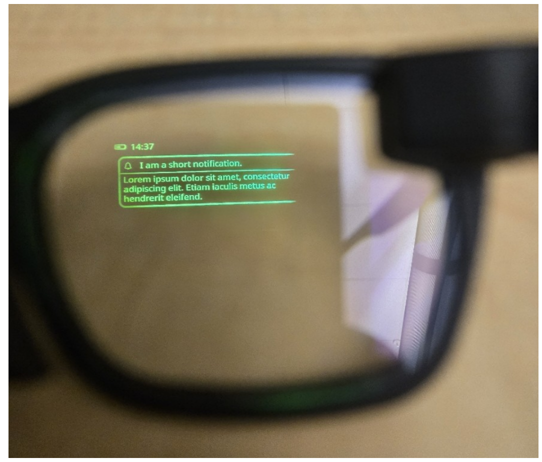
3 Methods

We conducted an experiment where participants wore Vuzix Z100 [48] smartglasses with a heads-up display for five days. This allowed us to better understand the experience of receiving real notifications in the field of view over an extended period, beyond the limits of a controlled experiment. While the HMD we used does not strictly meet the common definition of AR by Azuma et al. [2], we will nonetheless refer to them as AR going by the definition of Bowman et al. [6], which assumes that AR is an "approach that uses displays, tracking, and other technologies to enhance (augment) the user's view of a real-world environment with synthetic objects or information". Furthermore, this style of displaying information can be categorized as a display-fixed information presentation going by the classification by Billinghurst et al. [5].

The smartglasses were paired wireless with the participants' phone and displayed any notifications received on the paired phone as they arrived on the phone, similar to a smartwatch. The companion app allowed certain notification sources to be turned off, but we instructed participants to only turn off a specific app, if that app was also disabled on their phone. This allowed us to understand the types of notifications that would be beneficial or distracting to the users without them preemptively deciding to turn some notifications off. Since Do-Not-Disturb modes are implemented differently depending on the Android Version or manufacturer, the glasses were set to not respect the phones Do-Not-Disturb mode and delivered notifications always. The glasses feature a monochromatic green display in the center of the right lens with a 640 by 480 resolution and a FOV of 30 degrees. When receiving a notification,



(a) A long text notification on the smartglasses.



(b) A short text notification on the smartglasses.

Figure 2: Notifications displayed on the glasses. Note: Capturing this view with a camera is challenging and not entirely representative. The right side of the display is slightly cut off in this capture.

the title along with the notification source app name and icon is displayed with a maximum of 60 characters, and the content with a maximum of 410 characters (see Figure 1, Figure 2). If the text is longer, an ellipsis character (…) is displayed at the end of the limit to signify the cutoff. While the glasses are also available in a tinted version, we provided participants with the non-tinted version, which we paired with an optional sunglasses clip, that could be mounted on the glasses for use in bright settings. We validated this to work beforehand by asking several pilot participants to read sample texts in bright sunlight with the clip deployed.

Over the course of five days, participants were asked to wear the glasses for at least one hour before noon and one hour before the evening. Participants also installed an open-source research app on their phones that logged their notifications [50] without any of its content. We modified the logging application to indicate if the glasses were worn when a notification was received. This allowed us to understand how many notifications were received in general, and how many of them the participants would have received on the glasses. Every day at noon and in the evening, participants were asked to write a note about their usage of the device. They were asked about noteworthy experiences, thoughts on the device and about the time frame they wore the headset that period. The notes were sent to us using a codename that the participants created according to a specific pattern, which was unknown to the experimenter, ensuring participant anonymity. At the end of the five-day period, participants were invited to an in person interview, after which the log files were downloaded from their devices, and the glasses were returned. Each interview was conducted between the experimenter and the participant in person, in the form of a 90 minute semi-structured interview [51]. Each interview included all the following questions, with open ended follow-up questions depending on their responses.

- How would you rate the experience overall?
- Can you tell me a bit about your typical day?
- Can you describe a situation where the glasses helped you achieve a goal, and what made it effective?
- What was your first impression when you started using the glasses, and how has that changed over time?
- In what kind of situations did you decide to take off the glasses?
- Did the glasses make you change your thoughts on your phone notifications?

The notes and interviews are then reviewed using thematic analysis [7], where the data is first coded and then grouped into themes to extract the main points and common meanings that recur throughout the data. Coding was done using affinity mapping [3, 18, 20, 29]. Coding was performed by two authors, one of which had not been involved in this research prior in any form. Codes were created independently first and then discussed until agreement was reached on codes. Interview transcripts have been made using the Distil-large model [12] running locally on the author's machine. Transcripts were then double-checked for mistakes and cleaned for easier analysis. Cleaning involved removing duplicate words and filler words such as “umm” or “like”. In the notification logs, notifications are filtered not to include hidden system notifications or notifications from media playback. The category of notifications depends on the category the app's creator gave it. Not all apps producing notifications have included a category; therefore, some notifications will be categorized as “NA”. We have also cleaned the log from duplicates if multiple notifications were logged by the same app in the same second. Since the notification logging app would only work with Android, participants had to own and use a smartphone running Android OS 12 or newer. It has been found that there are no significant differences in personality depending on mobile operating system choice (Android or iOS) [17] and both platforms handle notifications in generally similar ways, so this population constraint should not restrict our results.

4 Results

For the experiment, we recruited eight participants aged from 22 to 29 years old (M = 26.8, SD = 2.3), with four males, three females, and one declining to answer. No other genders were reported. Vision was either normal (20-20, six participants) or corrected to normal with contact lenses during the experiment (two participants). Seven of eight participants were graduate students, with five of those majoring in Computer Science. Seven participants reported using Virtual Reality less than 60 minutes a week, and one participant reported using Virtual Reality for 3-5 hours a week. Only one participant reported using Augmented Reality regularly (3-5 hours a week), with the rest using it never. The small sample size was due to the requirements of the software and the multi-day nature of this study. Participants were asked to turn off their smartwatch notifications if they had one. Only two participants reported using a smartwatch outside of the experiment, which is in line with the age demographic for smartwatch ownership [23]. Ethics approval was provided by the Colorado State University institutional review board. Participants were paid $40 in gift cards for their participation and were recruited using word of mouth and a departmental mailing list.

4.1 Notification Logs

One of the participants encountered issues with the notification logging app, so their data has been excluded from the quantitative analysis, leaving 7 participants' log files. Overall, after notifications were filtered, 5863 notifications were logged. We found that our participants received an average of 159 notifications daily, with an average of 99 received while the glasses were connected and turned on (see Table 1). This means that more than half of the participants' daily notifications (62%) were delivered using the glasses, indicating a usage time higher than the minimum of two hours daily. This also includes notifications sent during sleep periods, which could mean that the ration of notifications seen on the glasses may be even higher. The journal notes also confirmed that participants wore the glasses for the majority of their day, specifically noting scenarios where they took the glasses off with wearing the glasses being the default during the study. Participants used informal usage expressions in their notes, so establishing a concrete hourly usage number is not accurately possible. Looking at the categories of notifications, we see that our results align closely with similar work, with messages (51.1%) and emails (10%) being the two most frequent notification categories (see Table 2). Several applications did not provide a category, so we cannot be sure what category the notifications were in. As for the phone settings, we saw that 46% were received with the phone on silent, 11% on vibrate, and 43% with sound. With the smartglasses connected, the numbers change slightly to 48% silent, 11% vibrate, and 41% sound. Looking at this setting on a per-user basis, we see that users largely did not change their ringer mode, and most notifications were delivered in one setting throughout the experiment. Less notifications were received on Monday, since the experiment started on Monday at noon.

Table 1: Notification average per day

Day	Notifications average	Notifications average with smartglasses
Monday	63	50
Tuesday	185	127
Wednesday	180	87
Thursday	177	106
Friday	191	126
Total	159	99

Table 2: Categories of notifications

Category	Number total	Smartglasses Number
Message	2820	1831
Other	1566	989
Email	624	378
Social	389	195

5 Interviews & Note Results

Our interviews and the journal notes the participants sent were combined in an affinity diagram with 406 notes (see supplementary materials). These notes were clustered into more minor themes, and then those clusters were again clustered into seven larger topics, which we will summarize in the following. Participants were asked to rate their overall experience with the glasses from 1 to 10, with one being a very bad experience with the glasses and ten being an exceptional experience, and rated the smartglasses 6.3 on average.

5.1 Notifications on Smartglasses

5.1.1 Interaction. Participants had many thoughts about how they would like to receive notifications on the smartglasses. First, six out of the eight participants mentioned they would like to reply to certain notifications on the glasses directly, inline with several previous experiments in laboratory settings [13, 39]. P5 reported "I definitely think there needs to be an interactive component a bit more where I can actually essentially handle the messages using just the glasses". Four participants expressed a preference for hands-free interaction, especially voice commands, to handle notifications. However, others were skeptical, with P6 stating they "couldn't imagine a way of how to do that in a way that's not terrible".

Another concern about interaction was the dismissal. The glasses had a button on the frame that could be used to hide a notification that was currently on the screen, but five participants reported that they were often in situations where they couldn't or didn't want to press the button to dismiss. P5 was explaining a situation in which they were presenting something and would have had to constantly press the button to dismiss notifications to not be distracted. Other participants reported that they would have liked a hands-free way to get rid of distracting notifications, when they couldn't use their hands but were distracted by the smartglasses.

5.1.2 Presentation. A second area of response was the way the notifications are presented. Four out of eight participants thought that they would often prefer not always to see the entire text of a notification, but would prefer an icon or just a short snippet, with the option to then access the rest of the notification when it was convenient to them. This access to notifications also extends to older notifications, since four participants wanted to be able to read all pending notifications on the smartglasses without needing to get their phones to do that. Lastly, three participants liked that they could read the entire notification immediately, even for long text notifications like emails, but noted that lingering notifications introduced unnecessary visual clutter and affected their concentration.

5.1.3 Importance. The most frequently mentioned area was the importance of notifications or their content. Six out of eight participants reported that the priority or importance of notifications should dictate how they are presented, or if they are presented at all. To begin with, it was reported that notifications for personal messages like instant messages or emails were the most important to the participants. This is reflected in the log files, where these categories accounted for most notifications received. Five out of eight participants stated that they do not want the smartglasses to display any notifications that are not relevant to them and keep those on the phone. One key factor for them to determine importance was whether a notification had any time-critical information in it. Participants felt that those notifications provided the most utility on the smartglasses since it helped them address things immediately, like reminders about calendar events that were coming up or messages that required quick responses.

5.2 Benefits from Smartglasses

Six participants have expressed that they often preferred using the smartglasses over their phones, and that using the smartglasses had helped them to use their phone less often. They reported that using their phones would introduce even more potential for distraction, with P4 saying "I'll go pull out my phone to check a notification, and then I'll be like: "Ooh what's this meme my sibling sent me on Instagram," and before I know it, I've killed 20 minutes there". Another reason for distractions seemed to be that participants would have noticed that they received a notification and wanted to check what kind of notification it was. With the smartglasses, they immediately saw what a notification was and whether it required action. Six participants said that they used the smartglasses notifications to determine if a notification was important enough to pause their current task to deal with it.

The smartglasses also helped some participants not to worry whether they missed something important, which was another big reason that they liked using the glasses. Four participants said they noticed notifications and especially phone calls only because of the smartglasses, which they would have missed otherwise because their phone is usually on silent mode (which 48% of notifications in the log files were delivered in). P2 said that "it reminded me of my parking expiring, which is a notification I usually miss on my phone".

While there were some reports about the glasses being too intrusive, participants said that the glasses did interrupt them but did not distract them from their task, as they found it easy to get back into their tasks. Especially in tasks where the hands were preoccupied, participants (five out of eight) saw the biggest advantage of the smartglasses. P5 said, " [The smartglasses] feels like it's the most beneficial in situations where [. . .] I'm doing something that requires both hands and I can't actively use my phone, but I would still like to know if there's something that has come up."

Turning to social situations, three participants liked using the glasses more than using their phone because they felt they could check their notifications without the other person noticing or without interrupting the conversational flow by *phubbing*, a phenomenon that has been described as snubbing someone in a social setting by concentrating on one's mobile phone. Lastly, we saw some general positive sentiments towards the glasses. Two participants stated that they would miss using the smartglasses and would like to own one going forward if they liked the looks. Four participants said that the notification feature alone was enough for them to be interested in such a product, with three of them finding the smartglasses reasonably comfortable.

5.3 Attentional Costs of Notifications

The interviews made it clear that participants found the smartglasses notifications interruptive. Six out of eight participants found that getting notifications on the smartglasses was more intrusive than receiving them on their phones and that they were difficult to ignore perceptually as well as ignore its content. P1 stated that "When I was ready I could pick my phone back up, but with the glasses, I felt like I didn't have a choice". In three instances, participants also reported that the smartglasses impeded their vision of the real world, primarily the display and the black frame. Some participants also reported that this meant they were heavily distracted from complex tasks, causing them not to wear it during those tasks.

5.4 Notification Ecosystem

One identified theme was what we call the Notification Ecosystem. First, five participants reported that the experiment changed their relationship with their smartphone notifications. They reported feeling surprised at how many notifications they receive daily and how many of those they do not need or that stress them. P6 said, "I never knew how much phone notifications really played a role in my life. [. . .] not in my life, in the way I go through my day [. . .] just how much they stress me." Participants also stated that they will turn off notifications from certain apps after the experiment is over, since they never look at them.

The second point of interest was the relationship between the smartglasses and the smartphone. Participants were unclear whether they wanted to dismiss phone notifications through the smartglasses, or whether both devices should be treated independently when dismissing notifications. This synchronous connection between phone and smartglasses was also highlighted, with four participants saying that they thought that some notifications were redundant since they were using their phone anyway and disliked getting the notification on their phone and smartglasses simultaneously. Occasionally, the smartglasses would be a little delayed in displaying the notification, which caused frustration. Lastly, it was mentioned that the smartglasses notifications are redundant when you need to respond and have to use your phone anyway for that.

5.5 General Usage Observations

Several themes also emerged not directly related to notifications, but more the overall experience with wearing smartglasses.

5.5.1 Obstacles for Adoption. Participants expressed their issues with the smartglasses, which would keep them from owning them. This feedback may be largely centered around the device we used, but highlights important considerations for future generations of these devices. While some initially found them novel or convenient in certain situations, they felt that the benefits did not outweigh the frustrations. Some noted that they do not get enough important notifications to warrant wearing the glasses. Overall, four participants said they wore the smartglasses primarily because of the experiment but would not choose to use them in daily life.

Besides this, participants experienced general discomfort using the smartglasses. An issue that four participants reported was that looking at monitors or televisions while using the glasses made them experience eyestrain or headaches. They also noted that wearing them made the monitors or televisions harder to read. Another issue was the brightness of the display. Since the device lacks auto-brightness, like the much more capable Hololens 2, four participants found themselves in situations where the display was uncomfortably bright in a dark environment or where it was not bright enough for outdoor settings, even with the sunglasses attachment. Some participants just felt that the frame design itself was not comfortable, however a larger obstacle for the smartglasses is the fact that all but two participants do not wear vision-correcting glasses in their daily life. Four participants said they were uncomfortable just wearing any type of glasses daily, not specifically the smartglasses. One of the two participants who regularly wear glasses stated that they would absolutely wear smartglasses instead, if it looked like their normal glasses.

Lastly, there were some situations that participants encountered where they had problems with the smartglasses. A common challenge that AR faces is the contrast between the real world and the display; our participants also ran into this issue. Four participants reported that they frequently had to face a uniformly colored wall to be able to read the text on the smartglasses.

Besides issues reading the screen, three participants stated that there are occasions where they would not want to have any kind of notifications, causing them to take off the glasses entirely. Some also reported that receiving many notifications in a short time from for example group chats would cause them frustration. The smartglasses' hardware was also mentioned as a problem. Three participants had liked to wear them while cooking but reported that the smartglasses fogged up more than normal glasses during cooking or that the lenses smudged more easily. Both of these problems probably occurred because the smartglasses are made of plastic, not glass like normal lenses. There were also concerns about durability, as participants feared they would break the borrowed device. Lastly, some participants encountered small software glitches, like animation freezes or notifications re-appearing after they had already been dismissed, though these were rare occurrences.

5.5.2 Societal Challenges. A significant theme found was the societal challenges that participants faced. The first area of concern is privacy. It is worth noting that the smartglasses used in the experiment does not have any recording capabilities since it lacks a microphone or camera. However, participants still felt uncomfortable in some situations because other people asked about being recorded. This caused some participants not to want to wear the smartglasses around other people. While some participants would rather not wear them in public because of their looks, most participants expressed not feeling comfortable about wearing them around others because of the attention they were getting or because they felt self-conscious about others thinking they were being recorded (six out of eight). Three participants said that they felt rude using the smartglasses in conversations or that they were drawn out of conversations when they received a notification during. While the glasses look close to normal eyeglasses, they seemingly are not unobtrusive enough to go unnoticed.

5.5.3 Device Improvement Opportunities. From the participant interviews, we found several opportunities where the smartglasses could be improved. Most participants (five out of eight) expressed that they felt the smartglasses should look even more like a pair of real glasses. P2 said, "I probably would be more open to wearing them a lot if they just look like normal glasses." Three participants, including one that thought they should look more like glasses, said that while they didn't like the looks, it didn't stop them from wearing them. In addition, participants expressed that they would want more features from the smartglasses. A commonly named feature (five out of eight) was the inclusion of especially audio input and output (I/O) as well as more display capabilities, like glanceable information about upcoming calendar events or timers. Some participants also mentioned that connection with digital assistants paired with audio I/O would be preferred.

6 Discussion

One of the key findings from our study was that notification management in smartglasses must balance usefulness with potential distraction. Participants generally placed their phones aside when they wanted to concentrate, indicating that any form of notification can be disruptive. However, this trade-off was considered acceptable when notifications were perceived as time-sensitive or relevant. Smartglasses were particularly useful when the phone was unreachable, either due to a conscious decision to focus or because situational constraints prevented phone use. Participants also reported feeling reassured that they were not missing important updates. Seemingly, participants felt smartglasses notifications were more interruptive right in the moment they were delivered, but that if they were important enough, the interruption was worth it. The phone also has more potential for distraction due to other apps such as games or social media, so while being more interruptive the glasses reportedly caused less distractions.

To address this, smartglasses notification systems should implement a more nuanced filtering mechanism beyond binary toggles for each app. Android OS already supports notification channels [15], allowing users to control notification categories at a granular level. Extending this functionality to smartglasses would allow users to receive only high-priority notifications, such as filtering app notifications to include direct messages but not group messages to avoid unnecessary attentional costs, something also suggested by

Lu et al [28]. Based on our findings, we propose the following priority model for smartglasses notifications to optimize attention and information delivery:

- **Urgent Priority**: Full-text pop-up
- **High Priority**: Icon and text preview
- **Medium Priority**: Icon and pull notification
- **Low Priority**: Only on phone or no smartglasses indicator

Urgent notifications should be displayed as a full text pop-up, as participants noted liking the ability to get all information if they feel its important to them in that moment, regardless of the interruption involved. High priority notifications would be displayed as a banner text with the source icon and a short preview of the content, similar to smartphone notifications. This reduces interruption, but still delivers important information. Medium priority notifications should be delivered unobtrusively by using an icon, to not obstruct the users vision, but still alerting them of new information. Lastly, low priority notifications should not alert the user on the smartglasses at all, as participants reported the highest benefit of the glasses with time-critical or somewhat important notifications. Faulhaber et al. [11] have looked into priority for AR notifications, and found that participants had challenges to distinguish between medium and high-priority notifications. So while there has been some early work into the priority display types, more research has to be undertaken to effectively differentiate between priority types.

Importantly, priority settings should be chosen carefully and be easily customizable based on user preference. We saw that the majority of notifications received were personal messages, but that messages cannot all be placed in the same category, as participants reported that content of the message and the timing of them strongly influenced their usefulness and willingness to be interrupted. An intelligent filtering and summarization mechanism that categorizes notifications based on urgency and context, similar to existing implementations in Samsung's One UI 7 [34] or Apple's iOS 18 [1], could improve user experience by reducing overload while maintaining awareness of essential information.

Our findings also show that smartglasses notifications influence phone usage. Participants indicated that while smartglasses allowed them to check notifications discreetly, interactions beyond passive viewing still required the phone. This suggests that smartglasses notifications should help users decide when retrieving their phone is necessary rather than completely replacing phone interactions. It also did not become clear from our experiment, whether notifications on the smartglasses should be treated as duplicates from the phone, or as separate instances. Users should be able to chose whether dismissing or opening a notification on the smartglasses also affects the notification instance on the phone.

Interacting with smartglasses notifications also posed a challenge, as our participants expressed a strong preference for more discreet and hands-free interaction methods, such as voice input, to reply to notifications. Participants reported that without the ability to reply, they would often still have to reach for their phones, which reduced the benefit of the smartglasses. These findings align with previous findings where participants wished they could reply to notifications [13, 39], so we suggest a layered approach to interaction, based on current literature [24, 35, 38]:

- **Primary Input:** Hand-gesture based interactions for reliability and when discretion is unimportant.
- **Secondary Input:** Unobtrusive alternatives like gaze-based interaction, voice commands, or multimodal combinations (e.g., gaze + pinch gestures) for discrete input (such as in social settings).

These types of input of course strongly rely on the hardware ability of the device in use, as not all techniques may be available, such as with the glasses we used. In the case of the Vuzix Z100, which has very limited sensors, adding hand-swipe gestures to the frame could provide better interaction possibilities.

Another notable finding was that participants who received fewer high-priority notifications often felt that the benefits of smartglasses notifications did not justify the frustrations. This suggests that smartglasses notifications are most valuable for users with frequent critical updates rather than general-purpose notifications. The IRC model [31] could be applied here, ensuring that only notifications with an interruption level of 1 (i.e., critical alerts) are enabled by default on smartglasses, reducing unnecessary distractions.

Despite their functional benefits, smartglasses notifications face significant challenges in social acceptability. A primary concern was the perception that smartglasses users might be recording others, even when the device lacked a camera or microphone. Participants frequently encountered skepticism from bystanders, highlighting a broader public distrust of wearable AR technology. However, most of the insecurity came not from other people but the internal fear that there *could* be a public backlash to the glasses. Participants often said they stopped wearing the glasses out of fear that other people might think they were being recorded, confirming the survey results of Rauschnabel et al. [41] in a real usage scenario.

To address this, designers should incorporate clear visual indicators, such as LED status lights, signaling when the smartglasses are recording audio and/or video. Additionally, physical shutters for cameras—similar to those found on some laptops—could help mitigate privacy concerns and improve public acceptance. This should, however, go beyond one manufacturer. It is unreasonable to expect every person to know precisely which smartglasses have recording capabilities, much less how that particular pair of glasses expresses that they are currently recording. This is highlighted in our findings, where onlookers were worried about their privacy, even though the smartglasses doesn't have cameras. Another self-conscious aspect of wearing the smartglasses was the looks of the device. Participants expressed that their not liking the way they looked on their faces was a big factor when deciding whether to wear them in public or not. This highlights the need for manufacturers to offer several frame designs for their product and to get inspiration from common and popular frame designs.

Beyond social concerns, physical comfort also emerged as a significant barrier to adoption. Participants, especially those not regularly wearing prescription glasses, reported discomfort when wearing smartglasses for extended periods. This suggests that smartwatches may be an easier entry point for users seeking wearable notification systems, as they do not require continuous wear on the face. The downside is that those notifications might be miss-able more often than smartglasses.

Other ergonomic challenges included eyestrain, display contrast, and frame design. Future smartglasses should prioritize lightweight, adaptable designs that cater to a diverse range of users. Features such as adjustable brightness and electro-chromatic dimming lenses could improve visibility in varying lighting conditions, enhancing overall usability. While some of these issues may be specific to the hardware used in our study, they nonetheless provide valuable insights for future smartglasses development. It should also be considered that users might wear the glasses while looking at a monitor for large parts of the day, so ensuring clarity of both the smartglasses display or the display behind it is critical.

6.1 Limitations

One limitation of this experiment was that we told participants to wear the glasses as much as possible during the experiment. This could have caused participants to wear them longer than they would have otherwise, potentially adding to their frustrations. Another limitation was the participants we used in the experiment. Only two of the participants (25%) wear vision-correcting glasses normally but corrected their vision with contacts during the experiment. According to the Vision Council [47], 63.7% of the US adult population wears prescription glasses, making our participant pool slightly skewed. Reports about the discomfort of wearing glasses might be exaggerated compared to the general population. Lastly, a limitation of this research is the device we used in the experiment. While the glasses are less capable than headsets like e.g. Microsoft Hololens 2 or the Magic Leap 2, those devices also do not allow the user to wear them the entire day and conduct business as usual, like the glasses we used. For example, in their in-the-wild experiment, Lu et al. [28] limited session times to 30 minutes, since longer exposure produced comfort issues. Therefore, some of our findings may be specific to the device class in question, however without an experiment with improved hardware that is unobtrusive and capable enough to be worn all day, we cannot specifically isolate our findings. We therefore caution against overgeneralizing findings to more capable HMDs, as the functionality and form factor may differ.

6.2 Future Work

In the future, we would like to implement and study different types of displays for notifications based on priority and context and evaluate our proposed priority levels. Our results show that priority and timeliness are key determining factors for how intrusive AR notifications can and should be. This could include examining color and size of notifications, among others. Second, our study showed that there are still concerns around privacy of onlookers, so the effects of smartglasses in conversations should be investigated more, especially with a focus on communicating the glasses status to other people in a conversation, such as the effectiveness of a camera indicator. Third, our participants reported feeling less distracted by the smartglasses notifications, and that they could resume tasks quicker. Measuring resumption lag when interrupted by a phone versus an HMD should be investigated in an experimental setting. Finally, more in the wild experiments should be conducted with more capable devices as the technology develops and more features can be implemented into such a small form factor.

7 Conclusion

We investigated the use of smartglasses for personal notification delivery. For this, we recruited 8 participants who wore a pair of smartglasses for a period of five days, during which it would display and log their phone notifications. Participants were asked to write two diary entries daily and send them to us, and were interviewed after the experiment to inquire about their experiences. Our findings highlight both the advantages and challenges of using smart glasses for managing notifications, and shine a light on crucial design considerations for future AR systems. While participants valued the ability to access notifications hands-free, reducing distractions, and improving notification awareness, key barriers such as interaction constraints, attentional costs, and social discomfort remain significant hurdles to adoption.

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