Exploring Attitudes Towards Increasing User Awareness of Reality From Within Virtual Reality

Joseph O'Hagan
School of Computing Science
University of Glasgow
Glasgow, Scotland
j.ohagan.1@research.gla.ac.uk

Mohamed Khamis
University of Glasgow
Glasgow, Scotland
Mohamed.Khamis@glasgow.ac.uk

Mark McGill
School of Computing Science
University of Glasgow
Glasgow, Scotland
Mark.McGill@glasgow.ac.uk

Julie R. Williamson
School of Computing Science
University of Glasgow
Glasgow, Scotland
Julie.Williamson@glasgow.ac.uk

ABSTRACT

The occlusive nature of VR headsets introduces significant barriers to a user's awareness of their surrounding reality. While recent research has explored systems to facilitate a VR user's interactions with nearby people, objects, etc, we lack a fundamental understanding of user attitudes towards and expectations of these systems. We present the results of a card sorting study (N=14) which investigated attitudes towards increasing a VR user's reality awareness (awareness of people, objects, audio, pets, and systems to manage and moderate personal usage) whilst in VR. Our results confirm VR headsets should be equipped with systems to increase a user's awareness of reality. However, opinions vary on how increased awareness should be achieved as our results also highlight differing expectations regarding: persistent vs temporary notification design, notification content and when, why and how awareness should be increased.

CCS CONCEPTS

• **Human-centered computing → Virtual reality**.

KEYWORDS

Virtual reality, awareness, card sorting, qualitative

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1 INTRODUCTION & RELATED WORK

Consumer virtual reality (VR) headsets predominantly prioritise immersion in virtuality over awareness of reality. Whilst video passthrough systems, which provide a VR user with a full view of their surrounding reality on demand [27], are becoming more commonplace they represent an extreme awareness mechanism pulling the user entirely out of VR [19]. Therefore, research has begun to explore systems to interleave reality awareness [26, 29] into the VR experience in a way which retains more immersion by, for example, contextually and selectively incorporating information regarding bystanders (nearby persons who cannot directly interact with the VR user's virtual environment) [26, 29, 38], nearby objects [16, 17] or peripherals into the virtual environment [7, 12, 24].

The often problematic nature of VR user interactions with bystanders [30, 32] has resulted in much focus on the development of systems aimed at increasing a VR user's awareness of bystanders. McGill et al. were the first to investigate how a VR user might be automatically notified of a bystander's existence through contextually augmenting photoreal avatars of the bystander into the VR scene [24]. However, while their approach proved effective at increasing awareness it also significantly disrupted the user's sense of presence in VR. Building on McGill et al's work, a range bystander awareness systems have been explored. Work has proposed haptic [10] (e.g. controller vibrations) or audio notifications (e.g. audio alerts [10, 26] and reducing in-VR audio [29]), although, the majority of work has focused on visual solutions such as text notifications [10, 29, 34] or avatars with a variety of abstract [10, 20, 26, 36] and photoreal aesthetics [11, 24, 38].

However, awareness system research has not focused exclusively on bystander awareness as much work has investigated how to increase a user's awareness of nearby objects and peripherals. While systems such as the *Oculus Guardian* [27] are already present in consumer VR headsets (to notify users when they reach the edge of a preset "safe" play area) work has begun to explore more sophisticated solutions for increasing object awareness. For larger objects, Huang et al. expanded on the existing systems present in consumer VR headsets and investigated how depth sensing could be used to provide a grid-like outline object of the user's full surrounding area [16]. Sakata et al, meanwhile, proposed two methods for increasing a user's awareness by superimposing 3D point clouds and virtual models of objects into the VR scene [17], an approach which they adapted from Simone's work on substitutional reality [37]. For smaller objects, McGill et al. investigated how peripherals (e.g. keyboards) but also how food items could be added into a VR

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scene [24] while Desai et al. proposed a system to allow a VR users to use a smartphone whilst in VR [6].

However, despite a plethora mechanisms for interleaving reality awareness into VR, at present, we lack a holistic understanding of user attitudes and expectations across these techniques of what elements of reality should be communicated to users as a priority and what motivates these preferences. Such an understanding is important as it can more clearly guide future development of awareness systems, better informed by user attitudes and needs, and provide insights into envision usage which are currently absent from the literature [32]. Whilst work has explored expert attitudes [10] absent from the discussion are consumer attitudes and insights. Yet, when considering future design innovations it remains essential to *"know thy user"* [8] as failure to understand the user's perspective can create dissonance between user and designer causing the development of an unsuccessful system [2, 3, 15].

To investigate this we developed a card sorting task to explore user attitudes towards the design of reality awareness within VR headsets. Our card sorting study (N=14) captured both quantitative and qualitative data and explored attitudes towards an increased awareness of: people, objects, nearby sounds, pets and systems to manage/moderate usage of VR. Our results show participants agree VR headsets should be capable of increasing a user's awareness of reality but opinions vary in how this should be achieved. Through our results we highlight several tensions regarding the design of these systems including: persistent vs temporary notifications, information content, and why/when awareness should be increased.

Our contribution: Using a card sorting study we investigated attitudes towards increasing a VR user's awareness of their surrounding reality whilst in VR. Our results confirm there is a need to enhance VR users' awareness of reality but also highlight that expectations of and attitudes towards how awareness should be increased are varied amongst consumers. We outline pertinent topics for future work on investigating reality awareness systems to consider regarding the design and use of systems to increase a VR user's awareness of reality.

2 DESIGN

We designed a card sorting task [4, 18] to explore attitudes towards 16 hypothetical approaches of increasing a VR user's awareness of reality whilst in VR. We opted for a card sorting task to capture both quantitative and qualitative data on participants' preferences. Prior work by Ghosh et al, which investigated if awareness was desired across a variety of scenarios found increased reality awareness was wanted in the majority of them [10]. However, as Ghosh et al's investigatory survey only captured quantitative data its results lack insight into how, why or even when different types of awareness are desired. Therefore, we designed our card sorting task capture both quantitative and qualitative data, providing us with a more complete understanding of user attitudes and expectations.

2.1 Card Statement Design

A list of 16 statements was created which proposed various approaches of increasing a VR user's awareness of reality (Table 1). The themes were:

- **Awareness of People:** Much work has explored increasing a VR user's awareness of bystanders [9, 10, 20, 24, 26, 29, 38], however, an understanding of attitudes towards such systems is missing. Due to the significant role awareness of people will play in bridging virtuality and reality [24] we included 7 statements on bystander awareness, derived from a range of prior work [10, 24, 29, 38].
- **Awareness of Objects:** Systems for object avoidance are already present in consumer VR headsets [27] as safety systems for users. Work has also begun to explore the augmentation of smaller objects (e.g. food items, peripherals) into VR as a usability feature [12, 24, 25]. We included 3 statements on object awareness to investigate how attitudes differ towards the inclusion of larger and smaller objects.
- **Awareness of Nearby Sounds:** Prior work has proposed the use of dynamic audio adjustment to increase a VR user's auditory awareness [29] of reality. Motivated by this and the known desire of VR users for an increased auditory awareness of their surroundings [10, 30] we included 2 statements on dynamic volume adjustment.
- **Awareness of Pets:** No prior work has investigated notifying a VR user when a pet enters their nearby area. For this reason, and to encourage a comparison between participants' attitudes towards people and pets, we included 2 statements about pet notifications.
- **Management & Moderation Tools:** Tools to manage smartphone usage have produced beneficial experiences for users [31, 33] and so recent work has begun to consider how similar systems might be built for VR usage [22, 35]. As such we included 2 statements concerning management of VR usage (social notifications [22] and time management [35]).

2.2 Task Design

Due to COVID-19 restrictions in our local area we conducted the study remotely (which prior work has established is valid for card sorting tasks [4]). *Zoom* [39], a videotelephony service, was used to meet with the participants and *Trello* [1], an online collaboration tool which allows users to sort labelled cards into categories, was used to perform the sorting task (Figure 1). *Trello* was chosen as it could closely replicate the task of card sorting in the lab - replacing physical sticky notes with digital equivalents which users could sort by dragging and dropping around the board. Participants were tasked with sorting statements into *"categories of agreement"* to indicate whether they agreed or disagreed a future VR headset should be capable of the feature described by the statement where the "categories of agreement" mapped to a 5-point Likert scale (Strongly Disagree=1, Strongly Agree=5).

2.3 Participants

14 participants (8 female, 6 male) completed the study. Participants ranged in age from 20 to 57 (M=24.71, SD=9.46). Participants indicated prior experience with VR headsets using a 5-point Likert scale (1=none, 5=a lot), (M=3.29, SD=1.27). All participants had at least "a little" prior experience of VR (none=0, a little=5, some=4, much=1, a lot=4).

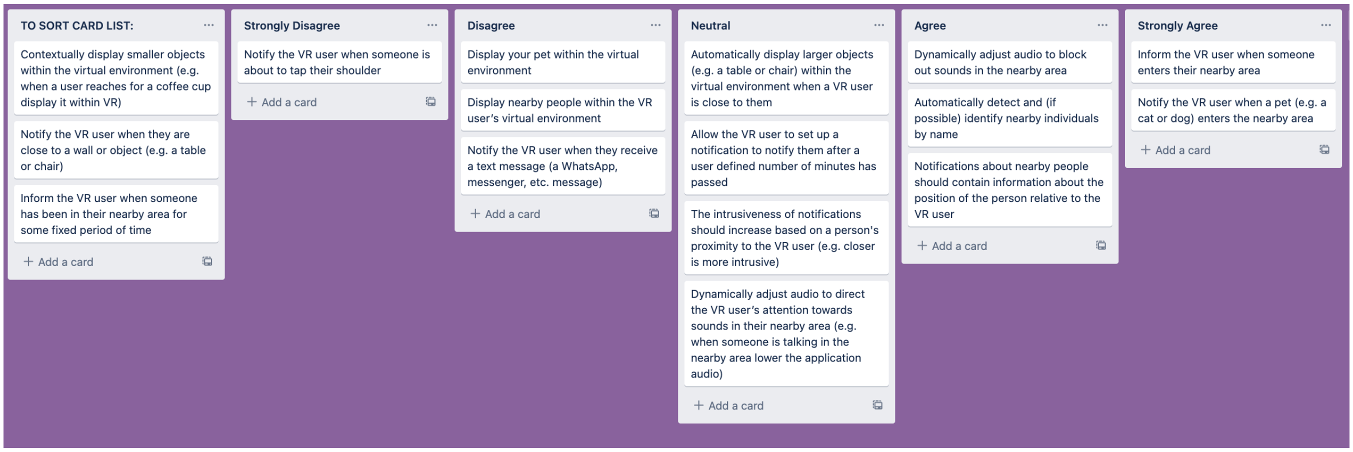

Figure 1: A screenshot of a Trello board showing an in-progress participant sorting the board

2.4 Procedure

Participants were recruited using social media and mailing lists. Participants who replied to the study advertisement arranged a time to conduct the study with the experimenter. At this time a link to the Zoom meeting and Trello board was sent to the participant. Once setup, the purpose of the study was explained to the participant - that current consumer VR headsets are equipped with safety systems to prevent VR user's accidentally walking into walls/objects in their surrounding reality and we were exploring attitudes towards increasing a VR user's awareness of other elements of reality more generally (e.g. people, pets, objects).

Next participants were told their task would be to sort 16 statements (each outlining one approach of increasing awareness) into 1 of 5 categories to indicated their level of agreement that a VR headset should be capable of a given statement. Participants were also told for any statements involving another person that this person was a bystander who could not directly interact with their VR experience / virtual environment in VR. It was explained that participants were able to adjust/update how they had sorted any statement at any time and that at the end of the experiment (when all statements were sorted) they would be asked to confirm they did not wish to make any additional adjustments. Finally, they were told to think aloud while sorting and to ask the experimenter for additional information about a statement whenever desired.

During the sorting process, the experimenter recorded participant quotes and probed the participant with follow up questions to investigate comments made or obtain clarity on things said (e.g. *"can you expand on that"*, *"why do you think that"*, etc). When the experimenter felt it necessary (e.g. the participant was being too quiet) they prompted the participant (e.g. *"why did you sort that statement as you did"* or *"you sorted statement X and statement Y quite differently, why is that"*). Statement order was randomised after each participant. Each participant took an average of 20 minutes to complete.

3 RESULTS

We calculated the mean and standard deviation of our participant's scores for each statement (Table 1) and created visualisations of them to show the distribution of responses (Figure 2). Participant comments were coded using initial coding [5] where statements were assigned emergent codes over repeated cycles with the codes grouped using a thematic approach. A single coder performed the coding, two coding cycles were completed, and the coder reviewed/discussed the coding with one other researcher.

3.1 Awareness of People

Participants agreed VR headsets should be capable of notifying the VR user when someone enters their nearby area. They also agreed that this notification should contain information regarding the bystander's position (relative to the VR user) and that notification of bystander existence should occur as soon as the bystander is detected. Attitudes varied, however, amongst participants in how this increased awareness should be achieved with the key topics discussed by participants outlined in the subsequent subsections.

3.1.1 ***What Communicating Positional Information Means:*** Despite agreeing a bystander's position should be relayed to the VR user, disagreement emerged over how this should be implemented. Specifically, whether this should be a *temporary notification of proximity* (e.g *P12: "just tell me when they enter/exit the circle [of] some set radius around me"*) or the *continuous relay of proximity and direction* (e.g. *P1: "I want to know exactly where that person is at all times"*). 5 participants preferred the former, stating a text notification was sufficient for increasing awareness, whereas 9 participants preferred the latter as they were not comfortable being made aware of existence without knowing, in real-time, where the bystander was located. However, these 9 participants also disagreed on how position should be communicated. Some believed UI notifications would be sufficient (e.g. a radar [36]) whereas others felt an avatar was more appropriate.

3.1.2 ***Temporary vs Persistent Notifications:*** Participants also discussed whether notifications should be temporary (e.g. a text

Statement: A VR system should...	Mean	Std.
Awareness of People		
(PEOPLE-1) Inform the VR user when someone enters their nearby area	4.36	0.50
(PEOPLE-2) Notifications about nearby people should contain information about the position of the person relative to the VR user	4.07	0.99
(PEOPLE-3) Automatically detect and (if possible) identify nearby individuals by name	3.79	0.89
(PEOPLE-4) The intrusiveness of notifications should increase based on a person's proximity to the VR user (e.g. closer is more intrusive)	3.50	1.40
(PEOPLE-5) Notify the VR user when someone is about to tap their shoulder	3.07	1.64
(PEOPLE-6) Display nearby people within the VR user's virtual environment	2.86	1.35
(PEOPLE-7) Inform the VR user when someone has been in their nearby for some fixed period of time	2.77	1.48
Awareness of Objects		
(OBJECT-1) Notify the VR user when they are close to a wall or object (e.g. a table or chair)	4.43	1.09
(OBJECT-2) Automatically display larger objects (e.g. a table or chair) within the virtual environment when a VR user is close to them	3.93	1.33
(OBJECT-3) Contextually display smaller objects within the virtual environment (e.g. when a user reaches for a coffee cup display it within VR)	3.43	1.02
Awareness of Nearby Sounds		
(AUDIO-1) Dynamically adjust audio to direct the VR user's attention towards nearby sounds (e.g. when someone is talking in the nearby area lower the application audio)	3.36	1.39
(AUDIO-2) Dynamically adjust audio to block out sounds in the nearby area	3.14	1.23
Awareness of Pets		
(PET-1) Notify the VR user when a pet (e.g. a cat or dog) enters the nearby area	4.21	0.70
(PET-2) Display your pet within the virtual environment	3.29	1.38
Management and Moderation Tools		
(MANAGE-1) Allow the VR user to set up a notification to notify them after a user defined number of minutes has passed	4.07	0.92
(MANAGE-2) Notify the VR user when they receive a text message (e.g. a message on WhatsApp, messenger, etc)	2.86	1.46

Table 1: The mean and standard deviation scores for each statement. Shortened codes at the start of each statement are used in Likert scale distributions (Figure 1, see next page).

notification pop-up) or persistent (e.g. an avatar) more generally. The 5 participants who said a text notification was sufficient to increase awareness stated any additional information/awareness would be *P12: "too disruptive and distracting"* to their experience. These participants aimed to increase awareness while retaining as much presence in VR as possible and felt text notifications best achieved this by providing minimal exposure to the disruptive notification, yet, still provided the information necessary to decide whether to (1) remove the headset to interact with the bystander or (2) remain in VR until their attention is requested (but, crucially, not be surprised when it was), *P5: "I just want to know that they are there then I'll decide... If I'm stuck with an avatar when I'm trying to ignore them that's super distracting"*.

In contrast, the 9 participants who wanted persistent notifications believed the awareness system could be *P1: "ignored and blend into the background"*. 7 of these participants, however, said using a photoreal avatar would be too disruptive to their experience because of (1) its contrast against the non-photoreal virtual environment and (2) it would not *P14: "fit correctly"* within all applications and might *P14: "be out of perspective or clipping through parts of the world"*. For these participants alternative avatar aesthetics and notification approaches, which better fit within a application's design (e.g. a UI notification like a radar), were said to be less distracting and so preferred.

3.1.3 ***When To Increase Awareness:*** Participants agreed that the notification of a bystander should be immediate upon detection of the bystander. 6 participants justified this stating a delayed response could easily be abused by a malicious bystander, *P11: "it sort of defeats the goal of increasing safety by increasing awareness of people if the person knows they have a few second time window to mess with the VR user"*. However, 3 participants acknowledged a *P8: "smarter, contexual"* awareness system could be developed to first provide some baseline level of awareness indicating someone was there and then increase awareness relative to the engagement between the bystander and VR user. This approach of increasing awareness relative to engagement is one approach put forth in the literature (first by McGill et al [24] and later expanded by Ceenu et al [9]) for how bystander awareness systems may work in practice. That 3 of our participants described systems similar to McGill et al and Ceenu et al's systems is positive as it indicates their approach of dynamically increasing/decreasing bystander awareness is a natural approach amongst some users.

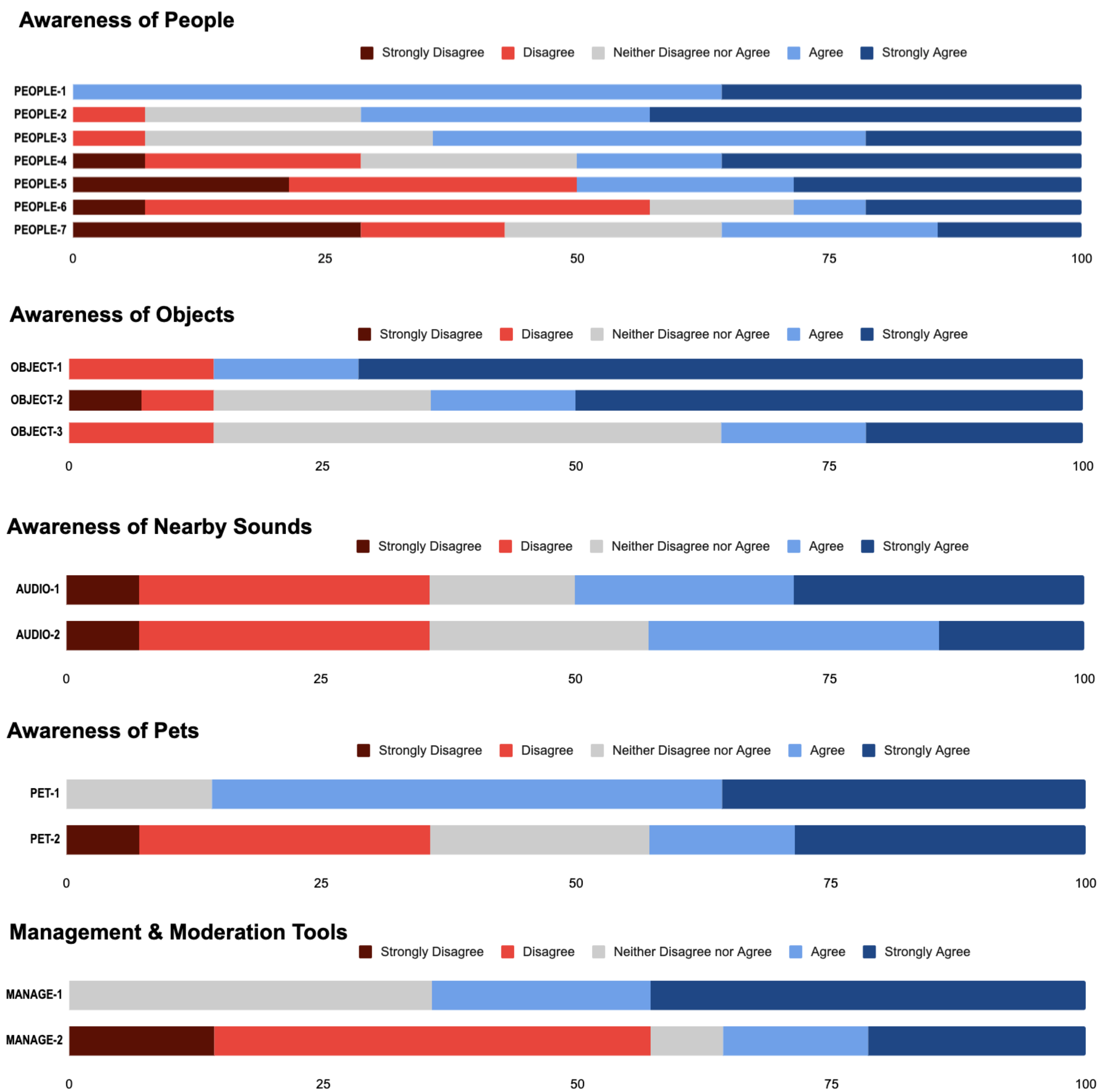

Figure 2: The distribution of participants sorting of the 16 statements (shown as a percentage). For statement mappings see Table 1.

3.2 Awareness of Objects

As expected, due to their inclusion in existing consumer headsets, systems to provide awareness of the surrounding physical space (e.g. when close to a wall or object) were viewed positively. More participants also agreed augmenting larger objects (e.g. tables/chairs) would be more beneficial than smaller objects (e.g. cups). Most participants were indifferent towards the latter with 5 stating they would likely use the feature and 9 that although they wouldn't personally use it they understood why someone would, *P14: "I'd never use it but maybe someone would"*. 3 participants discussed the conceptual difference between augmenting smaller and larger objects - that they viewed increasing awareness as a safety system meaning smaller object inclusion was unnecessary, *P11: "you increase awareness to improve safety and this [smaller item inclusion] isn't really that so it's not needed"*.

Surprisingly, when discussing notifications to indicate nearby walls, 2 participants said that any increase of awareness (including the existing systems in consumer headsets) was too disruptive to their experience. While they did acknowledge awareness systems were beneficial, these participants felt, for their own personal usage, they were unnecessary, *P7: "I agree there should be safety notifications for walls but I don't use them, I have good spatial awareness of where I use VR, they are just disruptive"*.

3.3 Awareness of Nearby Sounds

Dynamically adjusting in-VR audio to direct attention was slightly preferred over adjustments to block out nearby distractions (in-line with findings of prior work [29]). Participants difference in opinion appeared to be primarily due to attitudes towards volume levels being automatically adjusted. 5 participants spoke positively of this, *P8: "I like the idea of dynamic audio to maintain audio. I want to be immersed, if you can do things to keep me immersed without noticing that's great."*. 5 spoke negatively of it, stating the lack of control would *P12: "be very disruptive to my sense of immersion in VR"*.

3.4 Awareness of Pets

Participants agreed VR headsets should be capable of notifying the user when a pet enters the surrounding area. Participants viewed this as a safety feature to avoid accidentally hurting or tripping over the animal, *P6: "I don't want to accidentally step on it"*. However, opinion differed regarding how the user should be notified. 5 said it was essential a pet's position be communicated to VR user, stating animal bystanders, unlike most human bystanders, lack an understanding of personal space and would not know the VR user is unaware of their presence, *P11: "cats have no concept of personal space so if you don't tell me where the cat is I won't see it coming straight for me to try and trip me"*. However, 7 participants disagreed and instead felt a text notification would be sufficient. 3 justified this stating attempts to augment the pet within the VR scene would likely be too distracting but also that attempts to generate real-time avatars of it could result in *P4: "a weird caricature of your pet which might be uncanny valley or distressing"*. Furthermore, 4 said any additional information beyond notifying existence was unnecessary as upon being notified they would remove the headset to interact with the pet.

3.5 Management & Moderation Tools

Participants agreed systems to manage/moderate VR usage would be beneficial, often with the caveat that they should be optional features *P12: "nice things to keep track of but I'd want them all as optional things"*. 9 participants agreed a timer reminder would be useful while 5 were indifferent towards it (with 2 stating they thought it superfluous as they could easily use an alternative system *P11: "I can set a timer on something else like my phone"*). Incorporating text message notifications elicited a more mixed response from participants: 5 agreed, 7 disagreed, 1 was indifferent with their inclusion. Participants who disagreed said they would be too distracted by their inclusion as they would feel obligated to reply when a message arrived, *P7: "I want to use VR to be immersed and not distracted by things like that"*.

4 DISCUSSION & FUTURE WORK

The results of our card sorting study (Table 1, Figure 2) show, for awareness of nearby people, that our participants wanted (1) for VR headsets to be capable of notifying the VR user of nearby bystanders, (2) that these notifications should contain information regarding the bystander's position and (3) that notification of a bystander should be immediate upon detection of the bystander. Participants also expressed concerns with the use of photoreal bystander avatars believing they would be too distracting/disruptive to their experience in VR. Similar attitudes where held for increasing the awareness of pets, that is, the headset should be capable of increasing awareness but photoreal avatars may be too disruptive/distracting.

Regarding awareness of objects, participants were positive towards increasing awareness of larger objects which they believed posed a safety risk (e.g. without them they might accidentally walk into a wall or trip over a chair). Awareness of smaller objects elicited an indifferent response, however, with many participants believing this to be superfluous. Awareness of nearby sounds elicited a similar indifferent response, although, this is in-line with findings of prior work [29] on manipulating in-VR audio to increase awareness.

Finally, attitudes towards management/moderation tools were polarising with participants being in favour of a usage timer notification but against relaying text messages. Participants were negative towards text message notifications as they believed this would disrupt their experience in VR, which was similar to participants concern regarding photoreal avatars. This is interesting because it highlights a general sentiment expressed by our participants across all of the themes. That is, increased awareness is desired but participants are concerned with significantly disrupting their experience in VR and perceive awareness systems which augment, what they perceive as, too much reality into VR will have this effect.

4.1 Bystander Awareness Systems

Participants agreed VR headsets should be capable of notifying users of nearby bystanders, a finding in-line with prior works [10, 24]. Participants also agreed a bystander's position should be relayed to the VR user by the notification, however, differed in their view of what this meant. Either (1) allow the VR user to define an area which if the bystander enters the notification triggers (e.g. relaying the bystander's proximity) or (2) relay real-time information of where the bystander in the surrounding area (e.g. relaying the bystander's exact position). This too fits with the results of prior work which highlighted how some individuals if notified of bystander copresence without positional information are made uncomfortable/anxious and will remove the headset [29].

Participants disagreed photoreal avatars were suitable awareness notifications. Participants stated they believed this approach would be too distracting/disruptive to their experience because (1) of the contrast between it and the virtual environment and (2) as it would likely *"not fit"* correctly within the VR scene (e.g. it would be a different perspective, scale, clip with objects, etc). This is something prior work investigating photoreal avatars has not yet explored as prior works have instead opted to design the experiment/scenario to ensure the photoreal avatar *"fits"* correctly within the VR scene [9, 20, 24, 29, 38]. Therefore, while prior work has seen positive results with photoreal avatars, future work should explore their use in scenarios where they do not *"fit"* within the virtual environment and investigate what impact this has on user preferences.

Finally, participants wanted awareness to increase upon detection of the bystander and speculated if it was increased immediately that a malicious bystander could use this to their advantage. This is a valid concern [21, 30, 32] and a point often raised by researchers when justifying their work on bystander awareness systems [9, 10, 24, 26]. However, while it is clear bystander existence should be conveyed it is unknown if this alone is sufficient for increasing awareness or if more information is required (e.g. existence + identity). Future work, therefore, should investigate what baseline amount of information should be relayed when notifying a VR user of a bystander's existence across a variety of contexts. Prior work has already reported some users will exit VR if the bystander notification lacks information identifying (e.g. peeking out from under the headset to see who is there) [29, 32] and future work should explore what impact the addition/removal of information has when increasing awareness and, in order to develop awareness systems capable of dynamically providing awareness relative to VR user's engagement with the bystander, how/when this information should be added/removed.

4.2 Awareness of Pets

Participants agreed VR headsets should be able to notify of nearby pets although differed on their opinion of how; specifically, whether the pet's position should be relayed to the VR user or not. This, however, was fundamentally a usage problem as the main difference in opinion was due to how participants anticipated they would react to being notified of a nearby pet. Participants who said they would exit VR to interact with the pet argued positional information was unnecessary while participants who said they would remain in VR said it was. This highlights the need for future work to evaluate the usage of awareness systems to determine if this anticipated usage occurs in-the-wild. Future work should also work closely with pet owners (and experts in animal computer interaction [13, 14]) to identify the unique challenges of building pet awareness systems for VR users and VR usage around pets more broadly.

4.3 Object Awareness

Our participants agreed VR headsets should be capable of warning a user when they were close to objects/walls. This result was expected as consumer VR headsets already allow users to trace a designated safe area and be notified when near to an edge [27]. Recent consumer headsets, drawing from research on substitutional reality [37], have also begun to include systems which allow users to trace objects in their real world environment (e.g. tables/chairs) and place a virtual representation of them within their VR scene. These are positioned as a safety features for users and our participants were positive towards VR headsets having capabilities similar to these. Our participants were less positive, however, towards the augmentation of smaller objects (e.g. cups/food) despite prior work suggesting may be beneficial to the user's experience [24]. Instead, our participants viewed increased awareness of objects as primarily a safety feature. This sentiment/discussion of *"what awareness increases are appropriate"* is something prior work has highlight [28] where differing attitudes towards increasing awareness of reality emerged due to some augmentations of reality (e.g. those directly relating to increasing safety) being considered an necessity, due to the limitations of the technology, while others (e.g. augmenting smaller objects) were considered superfluous as their inclusion was not directly required to (1) enable the user to use VR or (2) ensure the VR user remains safe.

4.4 Managing & Moderating Use of VR

Our participants were positive towards the inclusion of systems to manage/moderate use of VR. However, sentiment towards including text message notifications was negative as participants felt they might intrude on their ability to immerse themselves within VR. This result is similar to the sentiment expressed by our participants across all of our themes - that increased awareness is desired but participants are concerned with disrupting their experience in VR too much. It is also similar to a result of prior work which investigated consumer attitudes towards VR and found concepts such as *"immersive"* and *"being in another world"* were strongly associated with VR [28]. VR viewed in this manner was something the user purposefully entered for immersion - the difference in experience between *"turning off your phone when the movie starts"* and *"watching in the browser while messenger is open in another tab"*. Inevitably then, irrespective of the approach taken [26, 32], there will likely be individuals who consider a given system to increase awareness too disruptive to their experience. However, as VR headsets will likely be equipped with a range of awareness systems and allow users to specify to what degree their awareness is increased and when [29], the goal of future work should be to determine whether enough individuals find a proposed awareness system to be beneficial/appropriate to include within a headset's awareness feature set.

4.5 Trial-and-Error Whilst Establishing Awareness Preferences

Our results also provide insights into the assumptions made by users when specifying their initial awareness preferences when, for example, setting up a headset's awareness features for the first time. Future VR headsets will likely be equipped with many systems to increase the user's awareness of their surrounding reality [29] and users will be required to specify when/how/if their reality awareness is increased. Yet, our results, in the context of the wider literature, highlight how assumptions made whilst selecting their preferences may lead to incorrect choices.

For example, our participants said they did not want a photoreal avatar of a bystander as the felt it would be too distracting to their experience. However, prior work investigating anonymous bystander notifications reported that some VR users resort to peeking out from under the headset to see who is there should they feel that insufficient identifiable information about the bystander is provided by the notification [29]. Consequentially, users may select an alternative awareness system (e.g. a radar [36]), believing it sufficient, not realising the importance of the absent information to them (e.g. identifiable information). Similarly, users may be too aggressive in their assumptions of how awareness should be increased, for example, initially selecting to automatically enable full video passthrough only to later decide an avatar is sufficient. It is likely then users will require some trial-and-error as they establish what awareness preference best fits their personal usage. How this process of determining preferences can be alleviated/streamlined, and if awareness preferences are universal or application specific, are other topics future work should also explore.

4.6 Pertinent Challenges For Future Work

Our paper highlights pertinent topics future work investigating reality awareness systems for VR users must address regarding their: (1) *design* and (2) *usage*.

With regards to their design, our results highlight differing attitudes towards whether awareness systems should be persistent or temporary and for bystanders/pets how/what positional information should be relayed. Participants were also concerned with the use of photoreal avatars for increasing awareness, believing they would be too distracting to their experience in VR; yet, this is the primary approach put forth in the literature for signally bystander copresence [9, 11, 24, 38]. Evaluating the use of photoreal avatars across a range of applications (e.g. where the avatar does not perfectly fit within the VR scene) and usage contexts (e.g. interactions at home, in the office, etc) must also be addressed by future work.

Regarding usage, future work must evaluate the use of these awareness systems outside the lab [23, 32], in their intended use settings, to determine if anticipated user behaviours occur in practice (e.g. taking the headset off to interact with the pet), to explore the impact of user behaviours on awareness system design and to investigate how to best assign awareness preferences. Also unknown, despite the many ways awareness can be increased, is what it means to increase awareness using one approach over another. Existing work cannot say, for example, given a range of bystander awareness systems (each known to increase awareness differently) which a VR user would use, when and why. While prior works have established increased awareness can be achieved, and our results provide insights into how users expect awareness to be increased, further work is necessary to explore the use of awareness systems in practice.

5 LIMITATIONS

A VR user's awareness of reality can be increased in more ways than it is feasible to evaluate through user study. To guide research and identify which topics are promising for future work an exploratory approach is required. To explore this, we used a card sorting study (a generative method) to investigate user attitudes and expectations towards increasing reality awareness whilst in VR. However, this only provides initial insights/results to guide future research and subsequent work employing evaluation methods (e.g. user studies) is essential and should build on our work. Additionally, although all of our participants likely had some prior experience interacting with pets (e.g. a cat or dog), not all participants were pet owners. Future work investigating awareness systems for pets, however, should target pet owners specifically to better identify the unique challenges of using VR headsets around animals

6 CONCLUSION

Through a card sorting study (N=14) we explored attitudes towards increasing a VR user's awareness of their reality whilst in VR. Our results indicate (1) VR headsets should be equipped with systems to increase a user's awareness of reality and (2) user attitudes/expectations towards how increased awareness should be achieved vary considerably. Our results highlight pertinent topics future work must address regarding: (1) *the design of awareness systems* by investigating topics such as persistent vs temporary notification design and notification content and (2) *the usage of awareness systems* by investigating topics such as if anticipated usage behaviours occur in practice and how awareness preferences should be established.

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