Assessing Social Text Placement in Mixed Reality TV

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ABSTRACT

TV experiences are often social, be it at-a-distance (through text) or in-person (through speech). Mixed Reality (MR) headsets offer new opportunities to enhance social communication during TV viewing by placing social artifacts (e.g. text) anywhere the viewer wishes, rather than being constrained to a smartphone or TV display. In this paper, we use VR as a test-bed to evaluate different text locations for MR TV specifically. We introduce the concepts of *wall messages*, *below-screen messages*, and *egocentric messages* in addition to state-of-the-art *on-screen messages* (i.e., subtitles) and *controller messages* (i.e., reading text messages on the mobile device) to convey messages to users during TV viewing experiences. Our results suggest that *a)* future MR systems that aim to improve viewers' experience need to consider the integration of a communication channel that does not interfere with viewers' primary task, that is watching TV, and *b)* independent of the location of text messages, users prefer to be in full control of them, especially when reading and responding to them. Our findings pave the way for further investigations towards social at-a-distance communication in Mixed Reality.

CCS CONCEPTS

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

KEYWORDS

Viewing Experience; Mixed Reality; Social TV

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Figure 1: A TV viewer in VR wearing a head-mounted display, and headphones for the audio. The figure shows one out of five conditions (*controller messages*). Users receive text-messages directly on a HTC VIVE controller. The controller grabs users attention with a 1 s haptic feedback.

1 INTRODUCTION

For most of us the experience of watching TV is firmly embedded in our daily routine: coming home from work/school followed by turning on the television. In the UK alone an average adult spends approximately four hours a day watching TV [25]. People engage in multi-screen activities alongside TV content [3, 6, 16, 17, 24, 27]. Often, this activity is social and related to the TV content, defined as "social TV" [5]. Because these messages are received over smartphone typically, our visual attention is split and vital moments on the TV might be missed. Can we interleave or collocate received messages with TV content in a way that better allows users to attend to the TV content? Netflix Party [18], for example, enables

Figure 2: The figure shows (1) *Netflix Party* [19], (2) *Com Hem Play VR* [11] , and (3) *MR Cmoar TV* [2]. *Netflix Party* enables watching Netflix remotely with friends and comes with a side chat while in (2) and (3) user can watch TV in VR only.

users to remotely and simultaneously watch Netflix with friends while having access to a shared chat (Figure 2-1). Others leverage VR to improve users' TV experience and explore new potential platforms (Figure 2-2 and Figure 2-3).

To the best of our knowledge, an investigation of preferred text message locations for social Mixed Reality TV is missing. We investigate text messages instead of alternative channels (e.g., speech) because prior work found that text dominated usage even when voice and audio modalities were available in social TV [16] , and because text is perceived as less obtrusive and requires less attention [12]. Moreover, Vatavu [29] highlighted the potential of the area surrounding the TV that enables new explorations of augmented TV spaces.

Our work provides findings from a user study (N=10) in which we investigated users' preferences when interacting with corresponding messages from both at-a-distance friends that share the same viewing experience and others who are not part of the shared-viewing experience. We conclude by discussing user preferences when conveying messages in social TV, and outline two promising directions for future research in the area of social TV in MR.

2 RELATED WORK

2.1 Social TV and Communication Modes

Work by Weisz et al. [30] found that text messages had a positive impact on social relationships during watching TV, despite being distracted by them. In particular, social communications through a chat during shared-viewing experiences can foster relationships and enable friends to integrate video content into their discussion. In a similar work by Tu et al. [27], authors developed a co-viewing room app that shows that shared content facilitates ongoing-conversation between friends. Geerts compared voice and text communication within a shared-viewing experience for interactive television [3]. Geerts outlined that voice chat is perceived as more natural; however, users with more experience in text-based communications would prefer text chat because it is easier to ignore text messages rather than audio messages. An in-depth field study by Huang et al. [12] aimed to understand the integration of communication through social television in our daily life and suggests that users prefer text over voice chat because the former is perceived as less obtrusive and requires less attention.

2.2 TV and Mixed Reality

Our experience of TV content in the future is likely to be enhanced by consumer MR headsets, which can bolster immersion (e.g., modifying the viewing environment to match the content [29], or providing unique listening experiences [15]) and social presence (e.g. [1, 16]). However, there is no evidence that significant social presence, such as through avatars or telepresence [16] is always desired, and our existing reliance on text messaging suggests that text will still have a significant part to play in interpersonal communications during social TV. Intriguingly, MR headsets also enable new ways of rendering text-based content, no longer limited to specific sizes and positions (e.g., small smartphone displays). Our work lies at the intersection of text-based social TV and Mixed Reality, examining how we might exploit MR headsets to better position/interleave social text messages with TV content.

3 VR-TV: CONCEPT, PROTOTYPE IMPLEMENTATION, AND USER STUDY

We implemented a prototype in VR that allows us to play video content back and render text messages to the user. We experimented with five different ways to convey social text messages while watching television:

- ***on-screen messages***: Messages are rendered directly on the TV (Figure 3-1).
- ***wall messages***: Messages are rendered on the right wall of the virtual environment (Figure 3-2).
- ***below-screen messages***: Messages are rendered below the TV (Figure 3-3).
- ***egocentric messages***: Messages are attached to users' field-of-view (Figure 3-4).
- ***controller messages***: Messages are rendered on the HTC VIVE controller (Figure 3-5).

We role-played a situation where participants are watching television together with an at-a-distance friend '*Stef*' and receive content-specific messages from him. Meanwhile, participants also receive text messages from other friends. All text message are displayed within the virtual environment and participants could directly speak to the system to communicate. Similar to a Wizard-of-Oz-Experiment, all pre-defined messages were rendered at set timestamps for the duration of five seconds. Example messages are outlined in Table 1.

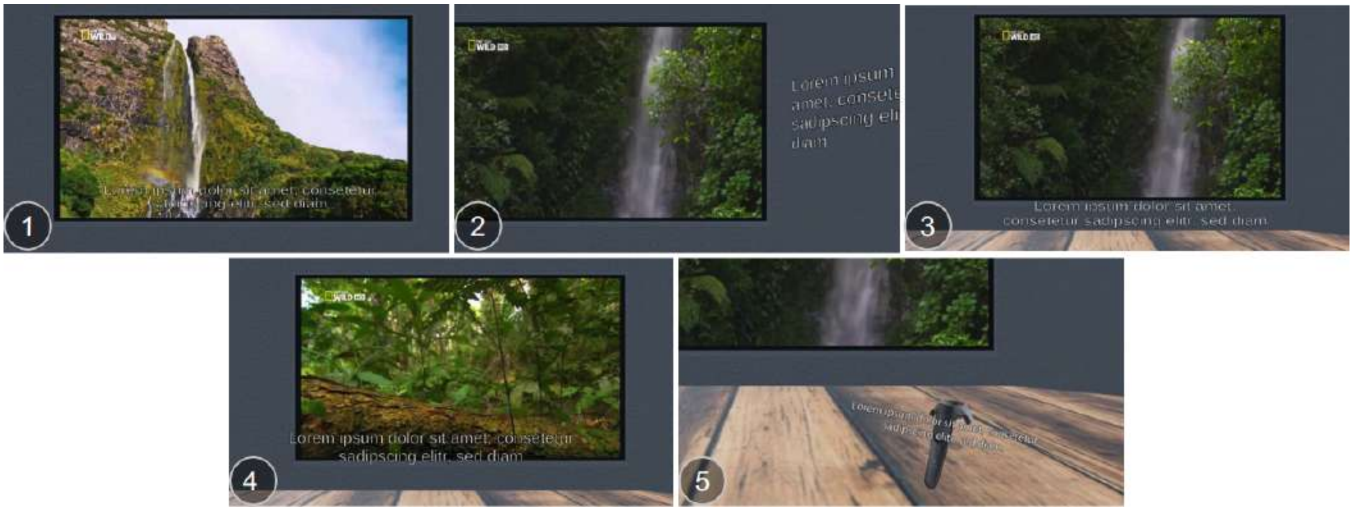


Figure 3: We experimented with (1) *on-screen messages,* (2) *wall messages,* (3) *below-screen messages,* (4) *egocentric messages,* and (5) *controller messages.*

3.1 Prototype Implementation

The prototype was implemented using the Unity gaming engine and C# [28]. We used an HTC VIVE HMD (2160×1200 px) which we connected to a VR-ready laptop (Razer Blade 15, NVIDIA GeForce RTX 2080) and to an audio headset. We used a nature documentary *National Geographic Documentary 2019 - Islands of Europe* [7] as video material. Our prototype implementation is publicly available on Github: *https://github.com/FlorianMathis/VRWatchingExperience*.

3.2 User Study

The user study was designed as a repeated-measures lab experiment. Conditions were counter balanced using a Latin Square. We had one independent variable **Message Display Position** with five levels: *on-screen*, *wall*, *below-screen*, *egocentric*, and *controller messages*. We measured following dependent variables:

- **User Preferences** (1="best"; 5="worst") based on the rank sum weight calculation [26]. We intended to elicit user preferences of the different message display positions.
- **Perceived Mental Workload.** We recorded participants' perceived mental, physical, and temporal demand, together with their effort, performance, and frustration with the NASA-TLX [9] after watching each two minute video excerpt.
- **Viewing Experience.** We asked participants after each condition to what extent they enjoyed the experience, how easy it was for them paying attention to the video and the text messages, and how comfortable they felt when responding to text messages while watching TV. All questions were answered on 5-point Likert scales (1="Strongly Disagree"; 5="Strongly Agree").

Additionally, we measured the perceived image quality and the perceived sound quality on a 5-point Likert scale across all conditions.

Content-specific messages
[Stef:] Oh, what species are the wales again?
[Stef:] What was the colour of the cat?
[Stef:] For what are the plants from the rainforest used?
Non-content-specific messages
[Peter:] Have you seen the rugby game last night?
[Tom:] Hey, are you still studying?
[Joseph:] How is it going today?

Table 1: Example messages rendered within the virtual environment. We distinguish between *content-specific messages* received from a friend who is part of the shared viewing experience and *non-content-specific messages* from others.

3.2.1 Procedure and Demographics. After filling a consent form and demographics, we introduced participants to all conditions. Participants then experienced the first condition and filled in the NASA-TLX [9] together with the self-defined questions. Participants then continued with the remaining conditions.

At the end of the study, we conducted semi-structured interviews to let participants walk us through their ranking of the conditions, get additional insights about the context(s) in which they would leverage VR/AR/MR for social TV, and asked them if they can think of alternative ways to convey messages in social TV.

The study took place at the University of Glasgow, UK and KU Leuven, Belgium. In both settings we used the same prototype implementation and hardware.

We recruited 10 participants (2 females, 8 males) aged between 23 and 36 years *(M=30.4, SD=4.5)*. One participant had never used VR before and 9 of them were non-native English speaker. Each session lasted for about 30 minutes.

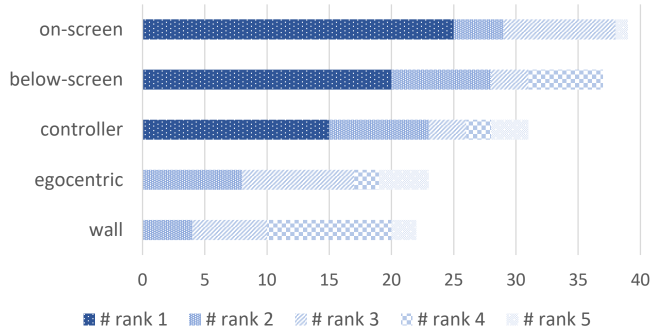


Figure 4: Raw scores were multiplied by their weight factor: ×5 for rank 1, ×4 for rank 2, ×3 for rank 3, ×2 for rank 4, and ×1 for rank 5, and then summed up to compute weighted scores [26]. *On-screen messages* achieved the highest score (39), and *wall messages* the lowest (22).

4 RESULTS

Although we did not compare the viewing experience in VR to the viewing experience on a TV in the real world, we recorded participants' perceived image and sound quality. We wanted to make sure that the image quality together with the audio is acceptable high and users feel comfortable. Across all conditions, participants rated both the video and audio quality as high with a median of 4.0. A Friedman test did not show any significant differences ($p > 0.05$).

4.1 User Preferences

When asking participants to rank the types of rendering the text messages within the virtual environment, *on-screen messages* was ranked highest with a weighted score of 39. *Below-screen messages* with a score of 35, *controller messages* with 31, *egocentric messages* with 23, and *wall messages* with 22 (Figure 4). This indicates that participants preferred *on-screen messages* over alternative ways to convey text messages in VR.

To get a better understanding of users' rankings, we asked them to walk us through the rankings. We grouped and sorted participants answers based on frequency and interest [23]. The majority of our study participants complained about the need for head movements in *wall messages* (8) and *below-screen messages* (5) because of the distance between the television and the text message. One participant even moved his field-of-view during *wall messages* to the middle of the television and the rendered text (Figure 5). *On-screen messages* were mainly described as a natural way of reading text (4) that does not involve any head movements. *Egocentric messages* were perceived as obtrusive that forces users to shift their attention to the text messages. Moreover, participants voiced that it was uncomfortable for them to read the text as their reading involves head movements that then shifts the text along the x-axis. Five participants stated they enjoyed *controller messages* because it feels "natural" and enables them to decide whether or not to read the message. Table 2 summarises our findings.

4.2 Perceived Mental Workload: NASA-TLX

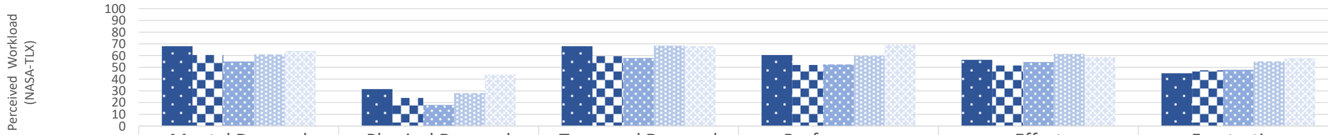
A one-way repeated measures ANOVA was conducted to determine whether there was a statistically significant difference in perceived

Figure 5: The figure shows a participant during the condition *wall messages* (top) and *below-screen messages* (below). In both conditions the participant had to explicitly move their head to read the messages; however, when reading text messages in *wall messages* they automatically moved their field-of-view for the entire duration of the video excerpt to the middle of both the TV and the position of the text, even when no text was displayed.

mental workload across all conditions. There were no outliers in the data, as assessed by inspection of a boxplot for values greater than 1.5 box-lengths from the edge of the box. A Shapiro-Wilk's test of normality showed that one condition (*wall messages*) was not normally distributed ($p < 0.05$). All other conditions are normally distributed. Due to the fact that ANOVAs are considered to be fairly *robust* to deviations from normality, we carried on with the one-way repeated measures ANOVA [8, 10, 14]. Perceived mental workload was not statistically significantly different across all five conditions, $F(2.529, 22.758) = 0.0286$, $p > 0.05$, partial $\eta_p^2 = .031$. There is no evidence that one condition is more demanding than others. Figure 6 shows all NASA-TLX dimensions.

4.3 TV Watching Experience in VR

We assessed participants' viewing experience on 5-point Likert scales. A Friedman test was run to determine if there were differences in enjoying the experience *("I enjoyed the experience.")* across the five conditions. The level of enjoyment decreased from *on-screen messages (Mdn=3.5)* to *wall messages (Mdn=3)*, *below-screen messages (Mdn=3)*, and *controller messages (Mdn=3)*, and to *(Mdn=2.5)* in *egocentric messages*, but the differences were not statistically significant , $\chi^2(4) = 4.773$, $p = .311$. We also ran a Friedman test to determine if there were differences in the ease of paying attention to the video and to the messages. There is no evidence in both cases that the level of attention is statistically significantly different across the conditions. The level of attention on the video slightly decreased from *wall messages* (*Mdn=3.0*), *below-screen messages* (*Mdn=3.0*), *on-screen messages* (*Mdn=3.0*), *egocentric messages* (*Mdn=3.0*), to *controller messages* (*Mdn=2.5*), but the differences were not statistically significant, $\chi^2(4) = 1.538$, $p = .820$. The same was



	Mental Demand	Physical Demand	Temporal Demand	Performance	Effort	Frustration
wall	68	31,5	68	60,5	56,5	45
below-screen	60,5	24	59,5	52	51,5	47,5
on-screen	55	18	58	52,5	54,5	48
egocentric	61	28	68,5	60	61,5	55
controller	64	44	68	69,5	59	58

Figure 6: The mean Task Load index score of participants as indicated in the NASA TLX questionnaire. We found no evidence that one condition is more demanding than others (p > 0.05).

found for the level of attention on text messages, $\chi^2(4) = 3.707$, $p = .447$. The level of attention on text messages slightly decreased from *on-screen messages (Mdn=4.0)*, to *below-screen messages (Mdn=3.0)*, *egocentric messages (Mdn=3.0)*, *controller messages (Mdn=2.5)*, and *wall messages (Mdn=2.0)*.

4.4 Semi-structured Interviews

4.4.1 TV Watching in MR. When asking participants about the context(s) in which they would use VR/AR/MR in social TV, we received mixed answers. In particular, the majority of our participants (7) mentioned that they would like to use such a system at home, if it provides a deeper sense of immersion. They explicitly mentioned that they would not use VR-TV in public spaces, such as on a train or on a bus, because of safety reasons. To the contrary, seven participants mentioned that a long journey on a plane would be a suitable application (e.g., [31]). Overall, the feedback can be read as a way to improve the viewing experience within *safe* environments (e.g., at home) and *long* journeys (e.g., on a plane) to enhance the experience compared to watching on a physical television (at home) or on a mobile device (on a trip).

4.4.2 Improvements. Five participants mentioned that they want to be in full control of the text messages. In particular, they prefer to have a "button" that enables them to show or hide these messages. Participants explicitly mentioned that they want to decide on their own when to read and reply to the messages. Three participants mentioned audio messages as an alternative, but at the same time they voiced that these would be more annoying. Interestingly, *P10* voiced that he would like to have messages from at-a-distance friends who share the same viewing experience via speech and messages from others via text: *"I would prefer to hear what my friend is saying [...] that is just how it works when watching TV normally [...] I don't want to [have that] for messages from others because it's kinda a bit crossing [the] boundary."*.

4.5 Lessons Learned and Implications

Similar to the sociability heuristic *"Minimize distraction from the television program"* for social TV proposed by Geerts and De Groof [4], we found that our participants prefer to minimise distractions from the TV experience when receiving text messages. Users do not want to be forced to read the messages, e.g., *egocentric messages* were perceived as annoying. Intriguingly, similar to the sociability heuristic *"Offer different channels and levels for communicating freely"* [4], one participant voiced that he prefers a bimodal communication approach: receiving messages as text and/or speech, depending on the sender. But at the point where a system uses both voice and text output to convey information to users, which messages have higher priority when both appear at the same time? Is it possible to mix multiple channels to enable high-quality communications during social MR TV watching? This is crucial as it remains unclear how *on-screen messages* interfere with novel approaches of subtitling in VR [13, 20, 21].

Condition	characteristics
below-screen messages	(+) well aligned with users' field-of-view (-) slight head movements are required
wall messages	(+) static background improves readability (-) necessity of head movements
on-screen messages	(+) perceived as natural (-) interfering with subtitles
egocentric messages	(+) controllable text position (-) too obtrusive
controller messages	(+) unobtrusive (out of FOV) (-) body movements required

Table 2: The table shows advantages and disadvantages of each condition stated by our participants during the study.

To summarise the learned lessons from this work, we outline two research directions that we think are promising for further investigations in the context of social TV:

- **Unique Affordances of MR** There has been lots of work that investigated text vs. audio communication in social TV [3, 12, 16, 30] – MR comes with unique affordances that haven't been available before. Social artifacts can be rendered with depth, anywhere around the user or in relation to the TV content. With less physical constraints (e.g., non-limited display sizes), how can we best integrate social communications into the TV viewing experience using MR?
- **Understanding Different Levels of Social Presence** How can we better facilitate communications in social TV, with, for instance, virtual 3D avatars (e.g., [22]) or live video feeds from at-a-distance friends? Should such user representations

be next to us (as in [16]), or next to the TV to enable us to see our friend's reactions interleaved with the content? Should the at-a-distance user's speech appear as if they are seated next to us, or originate from a user representation (e.g., 3D avatar) next to the virtual TV, or originate as if from the TV itself (similar to [15])? Logical next steps are to aim for a full understanding of the pros and cons of different social presence levels in MR (e.g., low: text, high: avatars, speech), detect and pinpoint when, if any, users want to switch levels (e.g., moving from 3D avatars to text), and their preferences in specific contexts.

5 CONCLUSION

In this paper we explored five different ways to convey text messages to users in social Mixed Reality TV using Virtual Reality as a test-bed. We found no evidence that one condition is more demanding than others; however, participants self-reported they prefer *on-screen messages* over *below-screen messages*, *controller messages*, *egocentric messages*, and *wall messages*, respectively. Expanding the way of transmitting text messages to users in social TV that goes beyond *on-screen messages* is promising; however, it is important to avoid interfering with users' viewing experience and provide users with full control over reading and responding to social messages. We envision that Mixed Reality changes the way users interact and communicate with at-a-distance friends during social TV, be it at home or in public (e.g., on a plane).

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