AR for Enhanced Video Viewing During Cardio Exercise

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Figure 1: We investigate how people currently watch videos during cardio workouts, and what that experience might look like in the future. The leftmost image shows a typical phone setup, commonly observed in gyms today. The middle and rightmost images show what the experience could look like with future augmented reality technology.

ABSTRACT

Watching videos during cardio is popular, but phone-based methods often fall short due to stability and usability issues. This paper explores how Augmented Reality (AR) can enhance video viewing during gym workouts. Observations from 86 users and 10 interviews revealed frustrations with screen size, placement, and comfort. We developed an AR video system for the Meta Quest 3S with three modes: Phone-like, Static AR, and Adaptive AR. In a study with 16 participants across three cardio machines, both AR modes were strongly preferred over the phone-like mode. Statistical analysis showed the phone mode significantly underperformed in terms of comfort, enjoyment, and exercise support. Adaptive AR was especially favored on the rowing machine for its motion-stabilizing effect. Participants emphasized the importance of screen stability and ergonomic viewing. While AR improved the experience, challenges remain, including headset comfort, treadmill-induced instability, and gym noise. Our findings highlight AR's potential for more ergonomic and engaging workouts, and the need for context-aware, customizable interfaces.

KEYWORDS

Augmented Reality, Cardio, Gym, Indoor, Virtual Reality, Visual Stimuli

1 INTRODUCTION

Regular moderate exercise has been shown to positively affect cognitive ability and overall well-being [3, 14, 24, 47]. In gym settings, many people pair their workouts with media consumption, most commonly music via wireless headphones. A 2017 survey reported that 49% of 18–24 year olds, 32% of 25–34 year olds, and 18% of those over 35 listen to music while exercising [20]. Music has been found to enhance physical performance and reduce perceived exertion [43]. Similarly, watching video content, particularly during cardio workouts, has grown in popularity. Studies show that visual media can increase exercise enjoyment, reduce perceived exertion, and support better workout adherence [13, 48].

However, while listening to music has been streamlined through devices like wireless earbuds, watching video content during exercise remains cumbersome. Consider a gym-goer watching a TV show while using a treadmill. They mount their phone on the machine's control panel, resulting in a small screen positioned far below eye level. As they move during the exercise, the viewing distance fluctuates, further disrupting the experience. Large mounted TVs, if available, lack personalization and are often poorly placed (too far, too high, or at awkward angles), while personal phones occlude machine controls and provide limited visual comfort. These limitations persist across cardio machines and worsen with increased intensity.

Previous studies confirm that personally selected video content can positively affect the workout experience [9, 13], but most experiments deliver content through traditional screens such as TVs, laptops, or projectors [16, 21]. Some work has begun to explore immersive technologies; for example, Jones and Ekkekakis [23] found that video delivered via a Virtual Reality (VR) headset increased dissociation compared to a traditional TV. However, we still lack a clear understanding of how different video presentation methods affect the viewing experience during exercise, especially under varying intensities.

In this paper, we explore how the presentation of visual media affects users experience during indoor cardio exercise. We focused on cardio exercise due to prior research and the common preference for watching visual media during such workouts, unlike less constrained activities like strength training or calisthenics, where visual distractions are less suitable. We begin with a week-long observation of gym-goers, followed by semi-structured interviews to understand current viewing habits, frustrations, and preferences. These findings inform the design of an Augmented Reality (AR) system that presents a video in three distinct viewing modes aimed at assessing user experience and identifying preferences. The modes are: **1)** a simulated phone screen, reflecting users' current approach to media consumption; **2)** a large static screen at neutral eye level, simulating a TV-like experience; and **3)** a large adaptive screen that adjusts to user movement and intensity, guided by findings from related research and screen size recommendations. The system and accompanying data is made available on our GitHub[1].

We evaluate the three modes across three cardio exercises and varying exercise intensities. Through Likert-scale responses, viewing mode rankings, and interviews, we investigate which presentation methods best support user enjoyment, minimize interference with exercise, and adapt to the challenges of movement and intensity.

Our results suggest that user viewing experience improves notably when moving beyond current consumption methods (e.g., phones) toward either a TV-like or adaptive presentation approach. Participant rankings revealed that different cardio machines lend themselves to different viewing modes: machines with broader movement patterns benefited more from the adaptive mode. While intensity-based screen adjustments were contested, some participants expressed dislike for these changes. They also expressed a desire for smarter screen adaptation during interviews. Training style also influenced preferences, suggesting that user customization could further enhance the viewing experience. We conclude by discussing these implications and offering design recommendations for future AR video presentation systems for cardio exercise.

2 RELATED WORK

To contextualize our study, we review prior work at the intersection of physical activity, media consumption, and immersive technologies. We first examine the cognitive and experiential effects of exercise, particularly in relation to audiovisual stimuli. Next, we review research on content consumption in Extended Reality (ER), highlighting the diversity of AR and VR media experiences. Finally, we explore how immersive technologies have been applied in exercise contexts. This review reveals both the positive impact of media on exercise engagement and the variety of Extended Reality (XR) implementations. However, we identify a notable gap: while XR systems increasingly support media-rich environments, few are explicitly designed to enhance video watching during exercise. Our work addresses this underexplored intersection.

2.1 Cognitive Impacts of Exercise

While exercise is associated with long-term cognitive benefits, cognitive function can be negatively affected during and immediately following strenuous activity [15, 19]. Covassin et al. [17] investigated the impacts of maximal exercise on verbal memory and found that participants' scores decreased, returning to baseline three days after the exercise bout. Other work has examined the cognitive impacts of both moderate and strenuous exercise. For instance, Ando et al. [4] reported a slowed response to peripheral visual stimuli during exercise, attributing it to impaired visual perception in the periphery.

These findings align with those of Miyawaki et al. [29], who observed a narrowing of the Useful Field of View (UFOV)[2] when users were presented with both static and dynamic content while wearing a Head-mounted display (HMD). Dynamic content was found to prompt a greater narrowing effect.

Together, this body of research suggests that the ability to process both verbal and visual information can be diminished during and immediately after physical exertion. However, despite these immediate cognitive effects, many individuals still enjoy consuming music or video content during exercise, pointing to the relevance of examining how media is experienced under these conditions.

2.2 Audiovisual Stimuli During Exercise

The effects of music on exercise have long been studied [42]. While some research has found no clear ergogenic benefit of music on performance [5, 36], other studies have reported positive impacts on exercise motivation [30, 44], adherence [31, 45], and even performance outcomes [7, 8]. These findings suggest that music can influence both psychological and behavioral responses to physical activity.

In parallel, researchers have investigated the influence of visual stimuli during exercise. A common finding across this body of work is that video content can enhance exercise enjoyment and induce a dissociative effect, helping users divert attention away from physical discomfort, which in turn lowers perceived exertion (Rating of Perceived Exertion (RPE)) [13, 16, 21]. This effect is even more pronounced when individuals are presented with audiovisual stimuli rather than audio or visual alone. The highest levels of enjoyment and dissociation are typically associated with personalized or self-selected content [9].

Recent work has explored how these effects translate to immersive platforms. Jones and Ekkekakis [23], for instance, examined the use of audiovisual stimuli in VR and found it to be more effective at inducing dissociation than conventional displays. These findings suggest a clear opportunity for immersive and adaptive media delivery technologies to enhance exercise experiences—but few studies have focused specifically on optimizing audiovisual content presentation for exercising users.

2.3 Content Consumption in XR

As immersive technologies evolve, XR platforms are increasingly being used as novel channels for delivering audiovisual content. Building on the positive effects of music and video during exercise, XR presents an opportunity to push beyond traditional displays and provide more engaging and immersive media experiences.

Watching movies in XR has already reached mainstream consumers through devices like the Meta Quest and Apple Vision Pro,

[1] https://github.com/Kristoffermg/ARVid

[2] UFOV: The area of your Field of View (FOV) in which you can detect objects and extract information in a single glance without moving your head or eyes [6]

offering rich, theater-like viewing environments. Much of the existing research on video consumption in XR has focused on the cinematic potential and the design of shared, social viewing experiences in virtual theaters [22, 34, 41]. Other studies have explored interactive and personalized viewing modes, finding that such experiences can lead to greater immersion and emotional investment from the viewer [12].

However, XR viewing experiences are predominantly designed for seated or stationary contexts. As such, their applicability in dynamic environments, such as during physical exercise, remains underexplored. This gap highlights the need for further research into how XR systems can be adapted to support media consumption while accommodating the physical demands and movement patterns of exercise.

2.4 Applications of AR and VR During Exercise

While XR systems are commonly used for passive media consumption, researchers have also begun to explore their active use in exercise and sports contexts. With the increasing accessibility of consumer-grade AR and VR headsets, there has been a growing body of work investigating how these technologies can augment the exercise experience or introduce novel modes of physical activity [2, 26, 39].

Several studies have examined the use of AR to deliver visual feedback to beginners and intermediate athletes in sports such as skiing, baseball, and basketball. These systems aim to guide users' technique or performance in real-time. Results have varied, with some studies reporting no significant improvement [52], while others observed positive effects on learning and performance [11, 25, 27, 46, 50].

Beyond coaching applications, other research has explored more interactive and motivational uses of AR and VR during exercise. Examples include racing against a virtual version of one's past performance [28], receiving real-time form cues and repetition counts [33], and training alongside virtual partners [51]. Czub and Janeta [18] further experimented with a body-overlay system that visualizes users as muscular avatars, aiming to enhance motivation through self-image augmentation.

Despite the breadth of these applications, most focus on performance feedback, training assistance, or gamification. The use of AR or VR specifically to enhance passive media consumption during exercise, such as watching video content, remains relatively unexplored.

3 DESIGN EXPLORATION

While prior research highlights the general benefits of media consumption during exercise and explores immersive experiences in XR, little is reported about **how** people actually consume media in gym environments today, especially in local or region-specific contexts. To ground our design in the realities of current gym-goers, we conducted an initial design exploration phase aimed at understanding media viewing habits during workouts.

Our design exploration was divided into three parts. First is a week-long in-situ observation of people in the gym performing cardio and seeing how they engage with video content. Second is a series of semi-structured interviews with the goal of gaining further insight into how people watch videos and their thoughts on the resulting viewing experience. Third, following the findings of the interviews, is an exploration of the FOV of a person doing cardio.

Figure 2: Cardio area of a local gym with 26 available cardio machines.

In this work, we focus specifically on media consumption during cardio exercise. This focus is informed by both existing research and our preliminary observations, which suggest that visual media is overwhelmingly consumed during cardio activities, where users are generally more stationary and rhythmic in motion. In contrast, media consumption during strength training (or similar) is less common, and such forms of exercise involve more varied and technique-dependent movements that introduce additional design complexities. Given these distinctions, we concentrate our work on cardio-based exercise scenarios, where visual content consumption is both more prevalent and more practically supported.

3.1 Observation

We went to a large local gym for one week (Monday to Friday) during February (2025) between peak hours (15:00 - 18:00). Each day, we conducted a ≈5-minute snapshot observation of the large cardio area (shown in Figure 2) and the people who were actively doing cardio at that time. We took notes of the amount of people doing cardio, which cardio machines they were using, and how many of them were engaging with visual content consumption[3].

Through our observations we observed 86 total gym-goers doing cardio. From this, it appears uncommon to do cardio without some form of secondary interaction. We observed people talking with each other and many people wearing in-ear headphones, while hardly anyone did cardio only. Of the 86 people observed, we saw 43 watching some form of video content on their phone, either in the hand or placed on the cardio machine. We see that cardio exercise is not performed without some form of distraction, be that talking with others, listening to music/podcasts, or watching videos on the phone, with the latter seeming the most popular as half of the gym-goers we observed were watching some form of video content.

[3]https://github.com/Kristoffermg/ARVid/tree/master/Data/DesignExplorationData/Observation

3.2 Interviews

In the same gym where we conducted our observation, we completed ten short in-person semi-structured interviews. We approached gym-goers who were watching content while performing cardio. One of the authors performed the interview while another took notes, writing down answers and any noteworthy remarks. Once all interviews were complete, we clustered the results to find common complaints regarding the current viewing experience, that were mentioned throughout the interviews[4].

Screen Size. With everyone we interviewed using their phone to watch video, we expected the small screen size to be an issue. This issue was mentioned by all ten people we interviewed, where the issue manifested in different ways, depending on the exercise and the person. On the stairmaster, one interviewee said *"I sometimes catch myself doing a 'shrimp-pose' (hunching over) because I get somewhat far away from the screen."* Another, on the treadmill, said that *"... details are hard to see, so sometimes I pick up my phone to get it closer to my eyes."* Lastly, regarding the viewing experience on the rowing machine, one said *"The screen is too small to see much, especially when I move back and forth a lot."*

The issue of screen size appears persistent regardless of exercise. While it may be more pronounced in certain exercises, like rowing, it does not detract from the fact that the issue is apparent throughout the exercise lineup.

Screen Position. Screen position is a complaint echoed by almost all people we interviewed, eight of the ten interviewed. With few exceptions, when watching video content during cardio, the phone screen is placed in front of the machines control panel, below the eye level. Interestingly the only two people we interviewed, who did not have a complaint about screen position were the ones who had their phone screens closer to eye level. This complaint was mostly expressed by comments stating that the screen is uncomfortably low comparative to where they would naturally look. The severity of the issue varies from a simple nuisance to someone saying *"... also placed too low which becomes annoying for my neck at times."*. The low screen placement of the phone also affects the viewing angle. One person we interviewed, who perform cardio on the treadmill with an incline stated that *"The viewing angle is bad especially with the incline. Then the phone screen is more pointed at my [torso] rather than my eyes."* The same complaint is echoed by another person, who also used the treadmill with incline, stating that *"My main issue with the setup is ... the angle that it gets with the incline."* As the viewing angle seems to be a side effect of the low screen position of current setups, especially with added incline during treadmill cardio, the issue may be mitigated by just bringing the screen closer to the level of a neutral gaze.

Intensity. We also asked the people we interviewed, at what intensity they performed cardio while watching video content, where all but one answered either low or medium intensity. While we did not get specific insight into why this is, we make note of a few comments that may provide some reasoning. One, who performed cardio on the rowing machine said *"Medium intensity, if I go too hard, my phone falls down."* Another, who sometimes run on the treadmill said *"I can't run and look down at the same time."*

From these comments on intensity, it appears that the viewing experience worsens as intensity increases with the current viewing approach. As with all issues, their severity varies from exercise to exercise. However, if the issue on the rowing machine is that the current setup simply does not support higher levels of intensity, then the current approach to watching visual content has room for improvement.

[4] https://github.com/Kristoffermg/ARVid/tree/master/Data/DesignExplorationData/Interview

3.3 Available Space in FOV

Figure 3: All cardio machines used in our design exploration. The elliptical is marked with a blue circle, row machine has a green circle, stairmaster has a red circle, and the treadmill is marked with a yellow circle.

We want to investigate ways of utilizing AR technology to mitigate the issues found with the State-of-the-Art (SOTA) viewing experience. For this, we investigate the available space in the FOV of a person doing cardio to assess viable placement options of a screen. To achieve this, we record two sets of Point of View (POV) videos of two of the authors performing cardio on the treadmill, the elliptical, the stairmaster, and the rowing machine. The machines are shown in Figure 3. All exercises were performed with a straight-forward gaze with the trainee wearing a pair of Snap Spectacles 3[5] set to record. All recordings were exported in a circular format, which captured the most scene information.

We analyzed the recorded POV videos to identify available free space where a video feed could be suitably placed. Figure 4 presents still images captured during each exercise, with red rectangles indicating the control panel. To avoid negatively interfering with the exercise, it is important that the video feed does not occlude this area. In the recordings from both participants, we consistently

[5] https://support.spectacles.com/hc/en-us/articles/360033392972-About-Spectacles-3

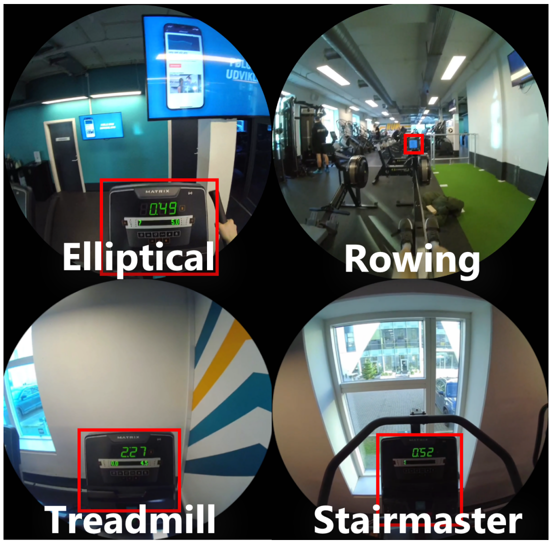

Figure 4: Still images from the recorded POV videos showcasing the freely available space above the machines' information screen. The red rectangles indicate the control panel, which we want to avoid occluding.

observe free space above the control panel, located centrally in the FOV across all exercises.

3.4 Design Considerations

Findings From Design Exploration. Through our design exploration, we investigated the currently employed method of watching content while exercising on cardio machines and found several complaints that contribute to a poor viewing experience. The notable issues are screen size, screen position, screen angle, and lack of support for higher intensity workouts. Placing the video feed above the machines' control panel corrects the position and partially the angle of the screen.

Anchoring the Video in AR. There are two main schools of anchoring virtual objects in AR: world anchoring and screen anchoring. Shogo Fukushima [37] Investigated anchoring modes and their effects on text readability through a HMD while walking on a treadmill. Their findings conclude that world anchoring significantly reduced mental workload and increased reading speed. They also note that their participants made additional effort to try to minimize head movement in screen anchoring mode to increase screen stability. Following the findings of Shogo Fukushima [37], we choose to world anchor our video feed.

Finding the Optimal Screen Size. When developing an optimal viewing experience, we naturally need to consider the screen size. Here, as a starting point, we consider the recommendations from the Society of Motion Picture and Television Engineers (SMPTE), whose recommendations are targeted at comfortable home viewing experiences, and THX who target the home theater experience. The SMPTE recurrently release a standard for viewing HDTV images, herein also specifying the amount of ones horizontal FOV a screen should occupy [38]. Their recommendation states that the distance to a screen should be 3 to 3.2 times screen height, roughly equating a horizontal FOV occupation of 30°. THX recommends a screen size corresponding to $Dist_{inch} \times 0.835$, giving around a 45° horizontal FOV occupation[6].

Both these recommendations are for sedentary viewing experiences, meaning that they may not translate entirely to a dynamic environment like the gym. We also want to keep in mind that, as previous research found, the UFOV narrows as cognitive load increases [4, 29]. Ando et al. [4] also found that strenuous exercise had a similar effect to the narrowing of the UFOV. This effect was found through participants performing high intensity cardio on a cardio bike. Following their findings, it is expected that a similar effect will occur with other strenuous cardio exercise. Based on this, we hypothesize that, as intensity increases, the size of the video feed should be reduced accordingly.

Based on the recommendations from SMPTE and THX, and the previous findings regarding the narrowing of the UFOV, we decide on three sizes for low, medium, and high intensity exercise respectively: Cinematic (60° horizontal FOV), THX (45° horizontal FOV), and SMPTE (30° horizontal FOV).

4 STUDY DESIGN

To evaluate user preferences for screen placement and size during cardio exercise at varying intensity levels, we conducted a within-subjects study in which each participant experienced all three viewing modes across all three cardio machines. To mitigate order effects, we employed a partially counterbalanced design inspired by a reduced Latin Square. Specifically, we varied both the sequence of machines and the sequence of viewing modes within each machine, while also ensuring that participants did not switch machines between consecutive trials. This allowed us to distribute condition orderings systematically across participants while maintaining a naturalistic exercise flow. Our independent variables were **cardio exercise** and **viewing mode**.

Each participant experienced three viewing modes: (1) a virtual screen fixed to the bottom of the cardio machine's control panel, simulating a phone viewing experience; (2) a large, static virtual screen anchored to the top of the control panel; and (3) a dynamically adjusting virtual screen that adapts to the viewer's exercise intensity, also mounted to the top of the control panel. Participants used all three modes on a treadmill, an elliptical, and a rowing machine. The stairmaster was excluded from this study due to limitations in available equipment. Had it been available in the university gym, it would have been included. After each session, they ranked the three modes for each machine and provided feedback, including their RPE, subjective impressions, and open-ended comments on the viewing experience. The study was conducted in the university gym during regular opening hours (08:30–16:00), with other gym members present and background music playing. Unlike a controlled lab setting, the gym environment allowed the system to be tested under realistic conditions reflecting its intended use.

[6]https://www.thx.com/questions/what-size-tv-should-i-buy-for-my-living-room/

4.1 The System

We developed the system in Unity (version 2022.3.48) using the Meta XR Core SDK (version 71.0.0), and it runs locally on the Meta Quest 3S. We use the center eye position as a reference for the user's head location. The SDK provides access to controller data, which we use to track the world-space position of the controller and controller input. The world-space position of the controller is used to anchor the video to a specific location. The system is entirely experimenter-controlled, with no user-facing controls; participants are not required to interact with the system or learn its functionality.

The placement of the virtual screens (except in the phone condition) was informed by our earlier design exploration in section 3 aimed at positioning them near a neutral eye level, just above the cardio machine's control panel. The phone condition simulated the common practice of gym users placing their phones directly on the machine, serving as a baseline for comparison.

The size of the static virtual screen was determined according to the recommendations from SMPTE, resulting in a physical size of 52.67 cm × 29.6 cm. This corresponds to a viewing distance of approximately 3–3.2 times the screen height, as advised by the SMPTE standard for comfortable viewing. The viewing distance was calculated as the average of participant eye-to-screen measurements across the three machines: 110 cm on the treadmill, 70 cm on the elliptical, and 115 cm on the rowing machine.

The adaptive screen supports three distinct sizes, mapped to exercise intensity levels. At low intensity, the screen occupies a 60° horizontal field of view (cinematic viewing). At medium intensity, it scales to 45° (aligned with THX recommendations), and at high intensity, it reduces to 30°, consistent with SMPTE guidelines. These adjustments aim to match the user's physical exertion with an appropriate visual load.

4.2 Measurements

Ahead of the study, we had participants fill out a questionnaire, gathering baseline information on age, sex, how often they do cardio, what other activities they do while doing cardio, whether they have tried AR and/or VR before, and what video content they wanted to watch during the study. For the latter, participants selected from a predefined list: *Family Guy*, *Brooklyn Nine-Nine*, *One Punch Man*, *The Office*, and *Parks and Recreation*. Collecting information on participants' cardio frequency is akin to determining their exercise motivation. Overstreet et al. [32] similarly noted that people with more intrinsic motivation, might enjoy exercising more regardless of a screen condition. Other research has used the Physical Activity Readiness Questionnaire (PAR-Q) [40].

After each viewing mode on a cardio machine, we asked participants to give their RPE[7] using the Borg CR10 RPE scale [49], ranging from 0 (no exertion at all) to 10 (very, very severe exertion). We selected RPE as our primary intensity measure due to its widespread use in exercise science and its practicality in naturalistic settings like the gym. While objective physiological measures such as heart rate or oxygen uptake (VO_{2max}) offer precision, they require equipment and setup not feasible for our in-the-wild study design. RPE has been shown to correlate well with such measures and is often used alongside them in prior studies [1, 40], providing a low-burden, reliable alternative that correlates well with objective markers while minimizing intrusiveness during exercise.

Participants also rated four statements on 7-point Likert scales: (1) *I found it cumbersome to watch the video*, (2) *At higher intensities it got harder to watch the video*, (3) *I found it enjoyable to watch the video*, and (4) *Watching the video enhanced my exercise experience*.

Following the completion of all three viewing modes on a machine, participants ranked the modes from best to worst and provided open-ended comments regarding their experience on that machine.

Finally, after completing all cardio bouts and ranking all viewing modes, we conducted a semi-structured interview to gather final reflections, preferences, and suggestions from each participant.

4.3 Procedure

The study took place in the university gym using three standard cardio machines: a treadmill, an elliptical, and a rowing machine, with participants wearing a Meta Quest 3S headset, as shown in Figure 5.

Ahead of a participant experiencing a viewing mode on a machine, we anchored the virtual screen relative to the cardio machines control panel. This was done using a controller button that toggled the video's position between following the controller's world-space position (for manual placement) and staying fixed in place (once properly aligned). The video was paused in between viewing modes. When experiencing the Adaptive mode, the experimenters changed the screen size upon participants being prompted to switch intensity levels. Participants performed the exercise as they normally would on each machine while watching the current video condition. No external sensors or tracking equipment were used beyond the Quest's onboard tracking.

Participants were first given a brief overview of the study procedure, after which they provided written informed consent. They then completed a pre-study questionnaire (see Appendix A.1), which gathered baseline information. During this phase, participants were also introduced to the Borg RPE scale and informed of the expected intensity ranges for low (0.5 - 2 RPE), medium (3 - 5 RPE), and high (6+ RPE) levels.

Once these tasks were complete, participants were guided to the study area where the experiment began. Intensities were always ordered from low to high. After completing each viewing mode on a machine, participants filled out a questionnaire regarding their experience (see Appendix A.2). Once all modes had been completed on all machines, participants were interviewed for additional comments using a semi-structured approach with pre-defined questions, shown in Appendix A.3.

4.4 Participants

We recruited 16 participants (15 male, 1 female, age 21 - 28, M = 25.13, SD = 1.62) from the university campus and university gym. All participants are active in their daily life, and are familiar with cardio exercise. We accepted participants of varying levels of fitness to ensure a diverse range of experiences and responses. Participants also did not need to be familiar with video watching during cardio.

[7]The RPE measurement has been shown to have a strong correlation with Heart Rate (HR) [35] and is thus a fast and practical tool for monitoring exercise intensity.

Figure 5: A user wearing a Meta Quest 3S while exercising on a treadmill, an elliptical, and a rowing machine.

All participants spoke fluent Danish with a good to fluent understanding of English. The study was conducted in Danish with the questionnaires being in English.

5 RESULTS

In total, 16 participants completed the user study, and data from all participants were included in the analysis. Based on the collected data, including Likert-scale responses, viewing mode rankings, and participant interviews, we examine the effects of different viewing modes on user experience. We apply non-parametric statistical analyses (Kruskal-Wallis) to the questionnaire responses and rankings, and conduct a thematic analysis of the interview data.

5.1 Statistical Analysis of Viewing Mode Rankings

All participant rankings of the viewing modes on the three machines are shown in Figure 6. On the rowing machine, the Adaptive mode was rated more favorably than the Static mode, suggesting that it performed especially well in this context. On both the treadmill and elliptical, the Static mode was generally preferred, ranking higher than the Adaptive mode. The Phone mode was consistently ranked lowest among the three modes. These rankings support the idea that the Adaptive mode is particularly beneficial during exercises involving a constant change in distance to the screen, such as rowing, where it appears to offer a clear advantage.

To further analyze participant rankings, we conducted Kruskal-Wallis tests on machine, mode, and machine_mode interaction to reveal if any of these factors had a significant influence on rankings. The results of the tests, shown in Table 1, report that there

Measure	Factor	chi-squared	df	p-value
ranking	m	0.06	2	0.9697
ranking	v	49.96	2	**<0.0001**
ranking	m_v	57.25	2	**<0.0001**

Table 1: Results of Kruskal-Wallis tests of participant rankings of viewing modes. Factors are v = viewingMode, m = machine, m_v = machine_viewingMode. Significant p-values are highlighted.

is a significant effect on rankings from both the machine_mode interaction and mode alone ($p < 0.0001$), while machine does not show significance ($p = 0.9697$). Following these results, we proceed with Dunn's post-hoc testing on viewing mode and machine_mode.

Measure	Factor	Z	p-value (adj)	r
ranking	Adaptive - Phone	-5.93	**<0.0001**	-0.494
ranking	Adaptive - Static	0.37	1	0.031
ranking	Phone - Static	6.30	**<0.0001**	0.525

Table 2: Results of Dunn's post-hoc test of mode interaction on viewing mode rankings. Significant p-values are highlighted.

5.1.1 *Post-Hoc Tests on Mode.*

We conducted Dunn's post-hoc tests adjusted using the Bonferroni method. The results of the Dunn's test on viewing mode are shown in Table 2. These results confirm an overall preference for both Adaptive and Static mode over Phone mode ($p < 0.0001$), with no significance in preference between the Static and Adaptive modes ($p = 1$). Calculated effect sizes (r), interpreted using Cohen's guidelines [10], also support this. The effect size between the Static and Adaptive modes is negligible ($r < 0.1$). The effect size between Adaptive and Phone mode shows a medium effect ($r < 0.3$), while the effect size between Static and Phone mode shows a large effect ($r < 0.5$).

Measure	Factor	Z	p-value (adj)	r
ranking	E.Phone - E.Static	3.86	0.004	0.322
ranking	E.Phone - R.Adaptive	4.50	0.0002	0.375
ranking	E.Static - R.Phone	-4.07	0.0017	-0.339
ranking	R.Adaptive - R.Phone	-4.71	<0.0001	-0.392
ranking	E.Static - T.Phone	-4.08	0.0017	-0.34
ranking	R.Adaptive - T.Phone	-4.72	<0.0001	-0.393
ranking	E.Phone - T.Static	4.075	0.0017	0.34
ranking	R.Phone - T.Static	4.28	0.0007	0.357
ranking	T.Phone - T.Static	4.29	0.0007	0.357

Table 3: Results of Dunn's post-hoc test of machine_mode interaction on viewing mode rankings. Non-significant p-values have been excluded. In factors, T = treadmill, E = elliptical, R = rowing machine.

5.1.2 *Post-Hoc Tests on machine_mode.*

The results of Dunn's test on machine_mode effect on rankings are shown in Table 3. The results have been shortened to only include significant p-values, of which 9/36 showed significance. The results once again reveal that the Phone mode is significantly less preferred compared both to the Static and Adaptive modes, with Adaptive mode on the rowing machine significantly outperforming the Phone mode ($p < 0.0001$).

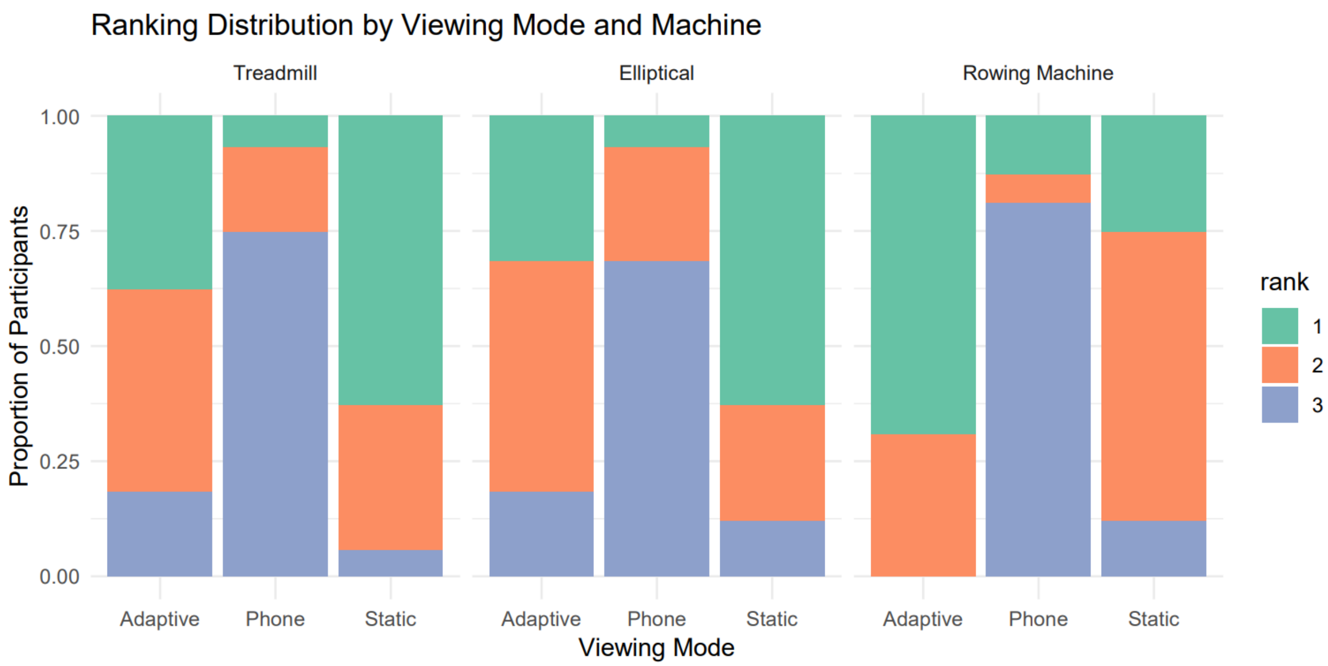

Figure 6: Participant ranking distribution of the three viewing modes `Adaptive`, `Phone`, `Static` for watching on the treadmill, elliptical, and the rowing machine. Ranks are ordered from 1 (best) to 3 (worst).

5.2 Statistical Analysis of Likert-scale Questionnaire

In addition to analyzing participant rankings of viewing modes, we also analyze participant responses to the Likert-scale questions that were administered throughout the study. The four questions are; "*I found it **cumbersome** to watch the video*"(Q1), "*At higher **intensity**, it got harder to watch the video*"(Q2), "*I found it **enjoyable** to watch the video*"(Q3), and "*Watching the video **enhanced** my exercise experience*"(Q4). The responses range from 1 (strongly disagree) to 7 (strongly agree). Response-distributions are shown in box plot form in Figure 7. Initial analysis of the box plots reveal that the Phone viewing mode is generally more disliked across all rating aspects, with both Static and Adaptive viewing modes being rated better overall. On Q3 and Q4 the gap appears to narrow between viewing modes, indicating that, while the Phone mode is worse overall, just having something to watch is still positively rated among participants.

To further investigate the participant responses, we conducted Kruskal-Wallis tests for all participant responses on our Likert-scale questionnaire questions, Q1 - Q4. All results are shown in Table 4. The test results show that viewing mode alone shows a large statistical significance ($p < 0.0001$) across all measures, while cardio machine does not ($p > 0.05$), The machine_mode factor does show statistical significance on ratings($p < 0.05$). Therefore, we proceed with Dunn's post-hoc testing on machine_mode and viewing mode, starting with machine_mode.

Measure	Factor	chi-squred	df	*p*-value
Q1: cumbersome	v	50.49	2	**<0.0001**
Q1: cumbersome	m	1.67	2	0.4348
Q1: cumbersome	m_v	52.61	8	**<0.0001**
Q2: intensity	v	28.21	2	**<0.0001**
Q2: intensity	m	4.78	2	0.0919
Q2: intensity	m_v	35.77	8	**<0.0001**
Q3: enjoyable	v	38.93	2	**<0.0001**
Q3: enjoyable	m	0.87	2	0.6471
Q3: enjoyable	m_v	40.46	8	**<0.0001**
Q4: enhanced	v	29.74	2	**<0.0001**
Q4: enhanced	m	0.26	2	0.8764
Q4: enhanced	m_v	30.93	8	**0.0001**

Table 4: Results of Kruskal-Wallis analysis of participant responses on Likert-scale questions Q1 - Q4. Factors are v = viewingMode, m = machine, m_v = machine_viewingMode. Significant p-values are highlighted.

5.2.1 *Post-Hoc Tests on machine_mode.*

The post-hoc test on machine_mode provided 36 total results, of which we only report significant p-values (see Table 5). Here, we note that no significance was reported for Q4, meaning that the presence of a video display enhanced the experience similarly across modes and machines with no significant pairwise differences after correction.

Of the significant values for Q1, the post-hoc comparisons revealed that the Phone mode was significantly more cumbersome than Adaptive or Static in several machine contexts, particularly on the treadmill, where the Phone mode differed significantly from five other conditions. This suggests that either the ergonomics or

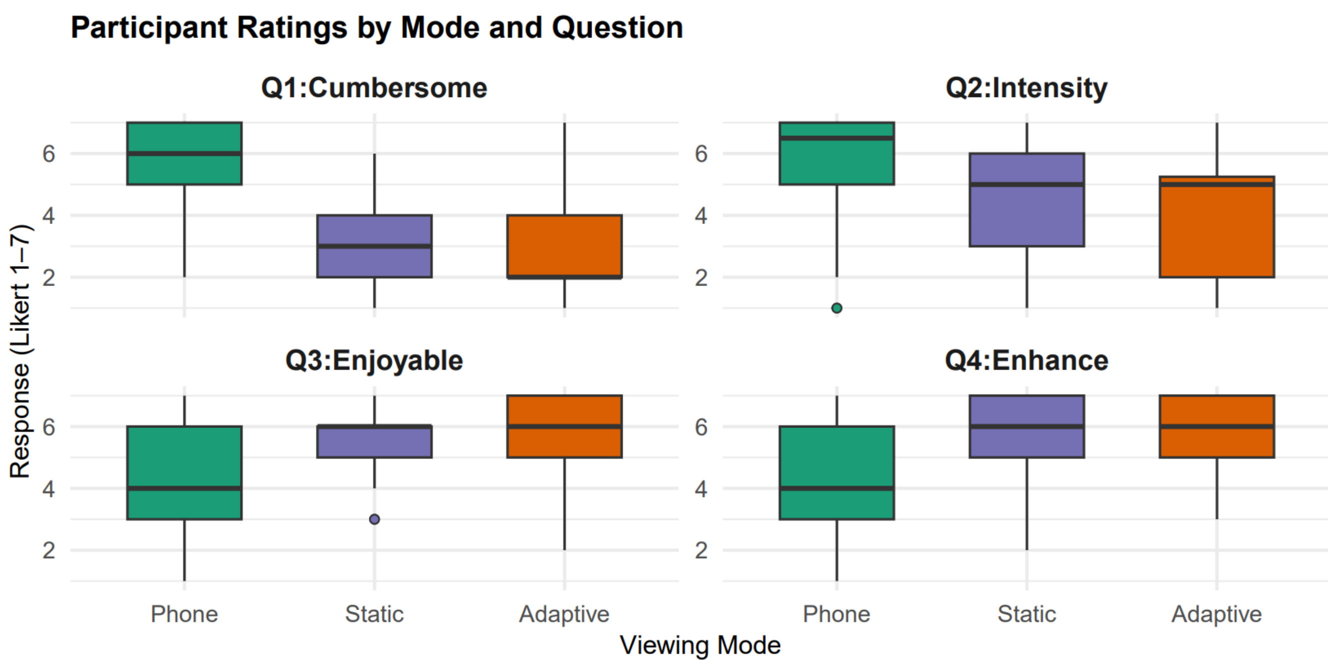

Figure 7: Participant responses across Likert questions. Responses range from 1 (strongly disagree) to 7 (strongly agree).

Measure	Factor	*Z*	*p*-value (adj)	*r*
Q1: cumbersome	E.Adaptive - E.Phone	-3.93	0.0031	-0.327
Q1: cumbersome	E.Phone - E.Static	3.09	0.0723	0.257
Q1: cumbersome	E.Phone - R.Adaptive	3.67	0.0086	0.306
Q1: cumbersome	E.Adaptive - R.Phone	-3.89	0.0037	-0.324
Q1: cumbersome	R.Adaptive - R.Phone	-3.63	0.01	-0.303
Q1: cumbersome	E.Phone - R.Static	3.24	0.0424	0.270
Q1: cumbersome	R.Phone - R.Static	3.21	0.0486	0.267
Q1: cumbersome	E.Adaptive - T.Phone	-4.7	<0.0001	-0.391
Q1: cumbersome	E.Static - T.Phone	-3.86	0.0041	-0.322
Q1: cumbersome	R.Adaptive - T.Phone	-4.44	0.0003	-0.370
Q1: cumbersome	R.Static - T.Phone	-4.02	0.0021	-0.335
Q1: cumbersome	T.Adaptive - T.Phone	-3.65	0.0094	-0.304
Q1: cumbersome	T.Phone - T.Static	3.71	0.0074	0.309
Q2: intensity	R.Adaptive - R.Phone	-4.32	0.0005	-0.360
Q2: intensity	R.Adaptive - T.Phone	-4.45	0.0003	-0.371
Q3: enjoyable	E.Adaptive - E.Phone	3.67	0.0086	0.306
Q3: enjoyable	E.Adaptive - R.Phone	4.01	0.0022	0.334
Q3: enjoyable	E.Static - R.Phone	3.2	0.0498	0.267
Q3: enjoyable	R.Adaptive - R.Phone	3.37	0.0269	0.281
Q3: enjoyable	R.Phone - T.Adaptive	-3.28	0.0377	-0.273
Q3: enjoyable	E.Adaptive - T.Phone	3.69	0.0082	0.307
Q3: enjoyable	R.Phone - T.Static	-3.42	0.0224	-0.285

Table 5: Results of Dunn's post-hoc test for participant responses on Likert-scale question Q1 - Q3 for machine_mode. All non-significant p-values have been excluded for brevity. In factors, T = treadmill, E = elliptical, R = rowing machine.

cognitive demands (or both) of the Phone mode were poorly suited to the treadmill.

Only two statistically significant factors are reported for Q2, being R.Adaptive - R.Phone ($p = 0.0005$) and R.Adaptive - T.Phone ($p = 0.0003$), suggesting that the Phone mode became significantly more difficult to watch as intensity ramped up compared to the Adaptive mode.

The results of Q3 once again reveals that Phone mode is the least enjoyable mode, with R.Phone standing out as the least enjoyable experience.

While the differences between viewing modes were statistically significant, the effect sizes ($r = 0.257 - 0.391$) indicate that these effects, though consistent, were moderate in magnitude. This suggests that while screen placement and behavior influence user preferences and experience during cardio exercise, the impact is incremental rather than transformative.

Measure	Factor	*Z*	*p*-value (adj)	*r*
Q1: cumbersome	Adaptive - Phone	-6.47	**<0.0001**	-0.539
Q1: cumbersome	Adaptive - Static	-0.7	1	-0.058
Q1: cumbersome	Phone - Static	5.78	**<0.0001**	0.481
Q2: intensity	Adaptive - Phone	-5.25	**0.0001**	-0.437
Q2: intensity	Adaptive - Static	-1.9	0.1724	-0.158
Q2: intensity	Phone - Static	3.35	**0.0025**	0.279
Q3: enjoyable	Adaptive - Phone	5.77	**<0.0001**	0.481
Q3: enjoyable	Adaptive - Static	0.84	1	0.07
Q3: enjoyable	Phone - Static	-4.94	**<0.0001**	-0.411
Q4: enhanced	Adaptive - Phone	4.84	**<0.0001**	0.403
Q4: enhanced	Adaptive - Static	0.24	1	0.02
Q4: enhanced	Phone - Static	-4.6	**<0.0001**	-0.383

Table 6: Results of Dunn's post-hoc test for participant responses on Likert-scale questions Q1 - Q4 for mode.

5.2.2 Post-Hoc Tests on Mode. Analysis of the Dunn's post-hoc test for viewing mode (see Table 6) reveals a general trend; the

Phone mode is consistently outperformed by both the Static and the Adaptive modes across all participant responses ($p < 0.0001$). There is no statistical significance between the Adaptive and Static modes with Q1, Q3, and Q4 reporting p-values of 1. The reported p-value of Q2 between Adaptive and Static displays a lesser p-value ($p = 0.1724$), although still not significant.

The effect sizes reveal that comparisons between the Phone mode and both Static and Adaptive modes yielded notable effect sizes for all questionnaire questions. The most notable of effect sizes were reported on ratings of cumbersomeness (Q1) (Adaptive - Phone $r = 0.539$, Phone - Static $r = 0.481$), indicating a strong practical difference in user experience. The comparisons between Phone mode and either other mode consistently showed larger effect sizes, while comparisons between Adaptive and Static mode are consistently shown to have small to negligible effect sizes (between r=0.02 and r=0.158).

The results from reported effect sizes reinforce the finding that, although both outperform the Phone mode, there is minimal practical difference between Static and Adaptive mode.

5.3 Thematic Analysis of Participant Interviews

In our post-study interviews, we asked participants eight questions (see Appendix A.3), covering several aspects of their experiences throughout the study. Participant quotes were transcribed verbatim. Light editing was performed for grammar and clarity where necessary, without altering the original meaning. We analyzed the interviews using an inductive thematic analysis to identify recurring themes across participant responses. Initial coding was performed by reading the transcripts multiple times and identifying recurring patterns. Codes were then grouped into overarching themes in iterative discussions. Table 7 shows our extracted themes and sample codes for each theme. In the following, we present the extracted themes and include participant quotes to illustrate these themes.

Themes	Sample Codes
Contextual Fit Between Viewing Mode and Exercise	negative_experience_with_adaptive_mode, machine_specific_gripes, screen_suitability_varies_by_machine
Ergonomic and Natural Integration	screen_should_fit_in_fov, exercise_elicits_specific_posture
Desire for personalization	participant_preference, preference_for_higher_intensity, preference_for_lower_intensity
Intensity-Dependent Desires	high_intensity_demands_more_focus, less_intense_exercise_grants_more_focus_on_screen
Distraction and Cognitive Load	size_change_caused_difficulties, positive_focus_divertion, negative_focus_divertion
Content and Enjoyment	focus_diverted_from_exertion, content_increases_exercise_enjoyment, boring_content_does_not_fit_high_intensity
Hardware limitations	headset_bouncy_on_treadmill, headset_induced_neck_pain, passthrough_imperfections

Table 7: Overview of extracted themes from qualitative thematic analysis of interview data. From left to right; The 7 extracted themes followed by sample codes representative of the themes.

Contextual Fit Between Viewing Mode and Exercise: Throughout the post-study interviews, participants made several comments, both positive and negative, regarding the contextual interplay between each viewing mode and the cardio machines. These responses add additional context to the provided viewing mode rankings and Likert-scale responses. As was observed in the collective rankings in Figure 6, there is a clear preference for the Adaptive mode on the rowing machine, while the Static mode is more dominant on the treadmill and elliptical. Through the interviews, we observe that the unique movements of the individual machines play a role in participants' ability to engage positively with the screens. On the rowing machine, while experiencing the Static mode, One participant described how the interaction between the movement of the exercise and the nature of the screen led to a worse experience:

> *"I would rather have been rid of the content entirely on [static, row] because I got motion sickness..."* [P8]

The more pronounced back-and-forth motion of the rowing machine thus appears to mismatch the stationary nature of the Static screen. Here, the Adaptive mode saw positive feedback from participants, with one noting the match between the movements and the screen:

> *"Since [adaptive mode] followed you, you did not think about the fact that you were moving at the same time."* [P6]

The "follow effect" is an aspect of the Adaptive mode that was mentioned in a positive light by several participants when mentioned in tandem with the rowing machine. However, participants did not notice the follow effect on the treadmill and elliptical, as expressed by one participant:

> *"[adaptive mode] is more noticeable on the rowing machine as you move more back and forth."* [P2]

This sentiment is echoed by many of our participants, which leaves the changing screen size as the only major noticeable difference between the Static and Adaptive modes on treadmill and elliptical. This aspect of the Adaptive screen is a point of contention among the participants, with some finding it distracting:

> *"The [adaptive mode] was more distracting... I focus a lot on the size changing..."* [P8]

However, while many participants express issues with the size changing of the screen, particularly on the treadmill and elliptical, others either do not notice the size changing, or only seem to dislike its execution:

> *"Static and adaptive have the same experience for me [on treadmill]."* [P14]

> *"Make the adaptive mode scale a little less over time, so it doesn't get so small - so maybe something in several different steps instead of just low, medium and high."* [P10]

Other participants liked the size changing in concept as well, but the specific sizing of the screen does not align with participant preferences:

> *" It's nice that it adjusts down in size when I go harder. But it can be a tad too small at the end."* [P16]

This theme and the above quotes highlight the connection between the screen and the machine on which it is experienced. In particular, we observe that the adaption to movement is well liked, fitting the context of cardio exercise. The screen size adaption is more contested, with no universal sentiment on the feature. This theme highlights the need for the virtual screen to feel naturally integrated.

Ergonomic and Natural Integration. During the interviews, many participants described aspects of their ideal viewing experience, where nearly all contained elements of ergonomic placement and size, and/ or having the screen feel like a natural part of the exercise. Two participants had comments regarding their ability to retain good posture while watching the screen:

> *"The video should fit what I am doing... My posture and form should feel natural as though I was not watching anything."* [P2]

> *"It is also important that I can maintain good posture/form while doing the exercise... [I don't want to] have to move my head/eyes a lot to see what's happening in the corners of the video... [I want to be able to orient myself] without having to actively move my eyes/head around."* [P14]

The ability to maintain proper posture has two-fold importance, both allowing for correct execution the exercise, while also ensuring ease of media consumption. With several participants making notes on the want to have good posture also opens the door for criticism of the Phone mode in particular, with participants describing their experiences with the Phone mode in a negative light. One participant said:

> *"The phone was quite bad, it promotes bad posture, and it was too small on many of the exercises... [phone mode] had a negative effect on treadmill and elliptical."* [P3]

Indeed, the placement of the Phone mode was contested particularly on the treadmill and elliptical, where its placement would have a more negative effect on posture. On the rowing machine, we observe some participants liking the lower placement of the Phone mode, while others like the higher-placed Adaptive and Static modes:

> *"On the rowing machine, I want to have a more straight upright back, so there I want the screen a bit higher..."* [P7]

This theme highlights the need for the virtual screen to be a naturally integrated part of the exercises. The unique desires from participants indicate that this is not obtainable from a strictly predefined system.

Desire for personalization: While not all participants made mentions of wanting to manually change aspects of their viewing experience, some did express the want for a less automated system. Some participant described their desire for wanting to manually place the virtual screen, with one saying:

> *"It would have been better if I could manually fix the placement of it... I would prefer to cover the information panel on the rowing machine, since it is right at the height where I would want to watch the video."* [P11]

Even having the system automatically adjust screen size based on intensity is not universally preferred, with some participants expressing the desire to adjust the screen size themselves:

> *"If it is a low intensity, I would want the big screen, and then if the intensity was higher, I could pick one that was a bit smaller... having another button to change the screen size would be perfect."* [P7]

These comments highlight some desire of control over the system, that was not made available to participants in this study. Even though the system already changes size based on intensity, we see participants commenting how they would like to be in control instead of the automatic adaption to higher intensity exercise.

Intensity-Dependent Desires: Indeed, many participants have provided comments on intensity-specific aspects of their viewing experience. Here, it is particularly interesting that some participants who had displayed a level of dislike towards the Adaptive mode, describe how they would like the screen to become smaller in size in accordance with exercise intensity. One participant, who had generally disliked the Adaptive mode throughout the study, said:

> *"I would have the screen adapt to the intensity, so it gets smaller when I sprint and bigger when I jog... The higher the intensity, the less disturbing the screen should be."* [P9]

The sentiment of the screen needing to be less distracting at higher intensity is shared by several participants. One participant summed up their thoughts on the interplay between intensity and the screen:

> *"To really push myself I cannot just zone out. I have to focus on the exercise and exerting myself and I cannot do that when I have distraction beside the exercise... It is the same with strength training. If I have a lot of weight, I want to focus on doing it right so that I do not destroy myself."* [P7]

Distraction and Cognitive Load. The aspect of increased cognitive load and the inherent distraction of visual content during exercise has also been mentioned by participants. Here, we observe both positive and negative aspects of having visual media be incorporated into the exercises. Some participants commented on the positive aspects of having something to watch during their cardio, aligning with findings of other research:

> *"[watching a video] makes it easier to exercise, you do not notice [that you are exercising] and just get it done."* [P1]

However, these positive effects are not universally experienced across viewing modes. Particularly, when experiencing the Phone mode, many participants had a negative effect:

> *"The [phone mode] did not make the exercises easier because I had to spend more energy on actually looking at it."* [P1]

> *"I didn't feel like pushing myself as much and watching the video when it was in [phone mode]."* [P16]

As previously observed in participant responses, some disliked the size changing of the video. One participant elaborated on the distracting nature of the Adaptive mode:

> *"when the screen changed size, it took my focus away from actually having to sprint. It changed size very gradually, so I didn't really notice it at first, but suddenly I noticed that it was smaller than it had been before."* [P9]

Another participant found that the video took too much of their focus to maintain their exercise intensity:

> *"[trying to focus on the content] ruins it for me and makes me not go as intense as I originally intended to... it's harder to pay attention to [the video] during intense training."* [P14]

Exercise intensity in fact seems to have had a notable effect on participants' ability to maintain focus on the video, with one participant commenting on the difficulty to maintain visual focus:

> *"[I would prefer] something more auditory so it is easier to keep track of the content at high intensity so that you can zone out with your eyes and just listen along."* [P5]

This theme highlights the importance of media presentation across intensity levels. We observe, that improper presentation in some cases lead to poor effects. At the same time, participant comments also highlight the positive aspects of distraction, which are observed when there is a match between participant, exercise, and screen.

Content and Enjoyment: Many participants made comments expressing the role of the content and the effect on enjoyment by having video content accompanying their exercise. These comments particularly provide context into the Likert-Scale responses, where we observed generally more positive scores on enjoyability and the enhancement of exercise. One participant highlighted the dissociation effect of watching something personally interesting:

> *"[watching a video] makes you forget the time and it feels like it's going much faster, as long as you choose some content you find interesting."* [P11]

While the general consensus is that the video provided a positive aspect to the cardio experience, mismatching video content and exercise intensity also seems to have a potentially negative effect, as expressed by one participant:

> *"The only thing that was not nice was when I got end credits during high intensity."* [P8]

The sentiment of the video having a less positive or even negative influence on the exercise with increased intensity is expressed by one participant as:

> *"I can immerse myself at low and medium intensity... On high intensity I feel [the video] is often more in the way than anything else... If I was going to be doing more high intensity, I would likely have picked something with more action."* [P7]

Participant comments highlight both the need for content to be personally of interest to them, and to match the intensity of the exercise being performed. This further underscores the importance of personally selected content.

Hardware limitations: During the interviews, participants were asked if they experienced any issues in regards to hardware and the system or encountered out-of-place elements. Here, we observe several comments regarding issues relating to the Meta Quest 3S headset. Specifically on the treadmill, participants had issues with the headset at higher intensity:

> *"High intensity on the treadmill was annoying because the headset started to bounce... I could not really tighten it any further, because it would start to hurt."* [P4]

The weight of the headset also had a negative effect on participants' viewing experience:

> *"The headset was heavy which put a bit of strain on my neck when you have to look down."* [P16]

The headset also limits the wearers FOV which some participants noticed when running on the treadmill, where they were unable to look straight ahead and see their feet:

> *"It seems more natural to look up at eye level. Except at high intensity on the treadmill, where it becomes difficult to know where your feet are when you look straight ahead."* [P9]

As we also used the built-in speakers of the headset, the auditory aspect of the media suffered, with one participant saying:

> *"It was hard to hear the sound at the end, as there were people training next to me which started to drown out the sound... I would have preferred to have been able to watch it with sound directly in my ears."* [P12]

Taken together, these themes highlight the diverse ergonomic, cognitive, and contextual needs of users during cardio exercise. The fit between user, exercise, and screen is a uniquely personal one, as reflected in the wide range of preferences and experiences shared by our participants.

5.4 Summary of Findings

Across all cardio machines, participants consistently ranked the Adaptive and Static viewing modes higher than the Phone mode, with the Adaptive mode being more well-suited to the rowing machine. Kruskal-Wallis and Dunn's tests confirmed that these rankings were significantly different on each machine, with the Phone mode receiving the lowest ranks overall. Likert-scale responses further supported these preferences, indicating that participants found the Adaptive mode more enjoyable, less distracting, and better suited to the rowing machine, while the Static mode experience was best suited to the treadmill and elliptical.

Thematic analysis of post-study interviews provided additional insight into these preferences. Participants appreciated the constant size in their FOV of the Adaptive mode, while the Phone mode was often described as difficult to follow or awkwardly placed. Together, the quantitative and qualitative results suggest strong improvements in overall viewing experience, when moving from traditionally employed methods of visual media consumption to an AR approach fit for the specific exercise in question.

6 DISCUSSION

The investigation into AR video viewing during cardio exercise yielded several noteworthy results, which demonstrate the potential of both static and adaptive AR displays to offer an improvement over traditional phone-based viewing experiences. While our study results confirm that AR can significantly improve the video viewing experience during cardio exercise, it also brought light to considerations regarding user comfort, hardware capabilities and the complexities of measuring RPE. This discussion will critically elaborate on these key outcomes, engaging with the existing literature to contextualize our findings and identify future research possibilities.

6.1 Influence of Video Content on Workout Experience

Analysis of the Likert questionnaire responses revealed a strong indication that participants perceived the video content as enhancing their overall workout experience. This observation aligns with existing literature on the impact of visual stimuli during exercise, which consistently demonstrates a positive correlation with increased exercise enjoyment and motivation [13, 16, 21].

Our selection of content was limited, in part due to the lack of a stable internet connection in the university gym. Thus our video content consisted of standard popular TV series like *Family Guy* and *The Office*. Prior research has shown a greater positive effect on exercise enjoyment with personally selected content [9], and thus future research should strive to allow participants to select from a wider range of shows, movies, and other visual content.

6.2 User Preferences and Adaptive Mode Design

During the studies, we observed that the participants generally experienced some form of a narrowing UFOV, which aligns with those of Miyawaki et al. [29], who reported a narrowing of the UFOV when users were presented with both static and dynamic content while wearing a HMD, implying a fundamental perceptual challenge under conditions of elevated cognitive load or during strenuous exercise. Our results suggest that during higher levels of exertion the participants cognitive load increased, thereby demanding considerations in the design of adaptive displays.

Additionally, several participants expressed that the 30° FOV used in the high-intensity Adaptive mode was too small. This feedback implies that while some degree of narrowing may be beneficial for minimizing distractions under cognitive stress, an overly narrow FOV can hinder usability or perceived comfort. Therefore, the high-intensity FOV should likely exceed 30°, while still allowing users to customize the FOV to match their individual preferences and tolerance levels. This highlights the importance of user-configurable parameters in adaptive display systems, particularly in scenarios involving varying levels of physical or mental demand.

6.3 Limitations

Several aspects of the study's design and execution require critical examination, as they may have exerted influence on the reported results.

6.3.1 Challenges in RPE Assessment. We employed the Borg CR10 RPE scale to prompt participants to reflect on their exertion levels throughout the study. Although the RPE scale is a widely used subjective measure, we observed notable variability in how participants interpreted and used it, despite providing standardized instructions. This variability, especially in the absence of prior experience with the scale, made the reported RPE values difficult to analyze meaningfully across participants or conditions.

However, the primary goal of incorporating the RPE scale was not to produce analyzable data, but rather to encourage participants to consciously maintain and monitor their exercise intensity. In this sense, the scale served its intended function by helping to stabilize intensity levels across the study, even if the reported values themselves were not used in quantitative analysis.

6.3.2 Impact of Cardio Equipment Familiarity. The study design did not explicitly control for participants' prior experience with the specific cardio equipment employed. This lack of control introduces the possibility of a learning curve effect, potentially influencing initial perceptions and responses to the system. Future research should consider explicitly assessing and accounting for equipment familiarity in order to mitigate this potential confounding variable.

6.3.3 Potential Cognitive Influence on Survey Responses. Participants in our study completed questionnaires immediately following each viewing mode on the various cardio machines. Each exercise bout finishes with high intensity, which should induce a greater negative effect on cognition, as shown by previous research [15, 19]. As such, it is plausible that the immediate post-exercise state may have introduced some cognitive load or fatigue, influencing participants' responses to Likert questionnaires and viewing mode rankings. This potential cognitive influence could have resulted in less nuanced ratings or a tendency towards quicker responses.

However, delaying the surveys to allow for potential cognitive recovery also presents a challenge. The immediate experience of the viewing mode, including the perceived exertion and subjective enjoyment, might be less accurately recalled if a significant time gap occurred between the exercise and the survey. Factors such as memory decay and the potential for other intervening thoughts or experiences could have influenced the accuracy of their responses. Therefore, the decision to administer the surveys immediately after each condition was a trade-off between capturing the immediate experience and potentially surveying participants with some level of cognitive impairment. The authors also played a part in overseeing participant responses, ensuring participants thoroughly understood each question, potentially mitigating some of the symptoms of fatigue.

6.3.4 Study Participants. Our study involved 15 males and 1 female, with an age range of 21-28 years. While this sample allowed for the exploration of evaluation our selected viewing modes, we acknowledge that it is not fully representative of the general population due to its specific age demographic and a notable male-to-female ratio. Future research should aim to include a broader age range and a more balanced gender distribution to enhance the generalizability of the findings.

6.4 Hardware Limitations

Since our research depends on future advancements in AR technology, we encountered several limitations with the Meta Quest 3S used in our studies. In particular, our participants mainly noted issues of weight and bounciness when running on the treadmill and general passthrough imperfections. As future technological advancements in the field of AR are made, we hope that these issues are addressed, further enhancing the AR gym experience.

6.4.1 Video Sound in Noisy Gym Environments. Some of our participants experienced situations where the speaker volume from the Meta Quest 3S was not sufficient. This was particularly an issue when the cardio equipment made more noise during higher intensities, or other nearby gym-goers were talking or exercising loudly. The decision to not use headphones or similar audio equipment, was made by us to ensure ease of communication with participants during the study. With participants receiving verbal instructions, it was important that these instructions were clearly heard and understood, to ensure study procedure adherence.

However, we acknowledge that clear audio plays a vital part in an immersive experience, potentially further enhancing the impacts of audiovisual stimuli, which prior work shows has beneficial effects [13, 16, 21].

6.4.2 Balancing Visual Immersion and Safety. Some participants made notice of the hindered FOV induced by the Meta Quest 3S, which narrows the FOV of the wearer to $96^{\circ} \times 90^{\circ}$. This prevented participants from fully seeing their lower body and feet placement, which was especially hindering on the treadmill when running. While AR offers the potential for immersive visual experiences, it is important to ensure that it does not compromise users' awareness of their physical surroundings, particularly in dynamic and potentially hazardous environments such as a gym. We hope, that as advancements in the AR field are made, that the FOV continues to increase, thus improving both potential immersion and safety during exercise.

6.5 Future Design Recommendations

With a growing body of research of accompanying visual media consumption during exercise, especially through XR [23], we present our design recommendations for media presentation of future systems, based on our findings.

6.5.1 Ensure Constant Screen Size. Our research shows positive participant feedback on the "follow effect" of the Adaptive mode, with it being particularly valuable during exercises such as rowing, where the distance to the virtual screen fluctuates constantly. On more stationary movements like the elliptical and treadmill, this effect is less noticed by participants. Based on this, we recommend future systems implement a similar approach to ensure a constant size in the FOV of users.

6.5.2 Allow User Customization. With every user being unique in their execution of an exercise and their preferred posture, we recommend increasing user customization, allowing for users to adjust screen placement and size. Our participants displayed differing opinions on the optimal size and placement, highlighting the importance of fitting a system to the individual user. In extension of this, we also note that our participants had differing opinions on both the execution of the screen size changes and its existence. Some would rather have been rid of it entirely, while others expressed a desire to be in control of it. Consequently, we recommend future system allow for an option to enable variable screen size, with further user control available to those who prefer a less automated system.

7 CONCLUSION

This study demonstrates that Augmented Reality significantly enhances the in-gym video viewing experience, effectively addressing prevalent issues of usability and stability. While both Static and Adaptive AR modes are preferred over traditional phone setups, optimal user experience hinges on context-specific design, particularly the Adaptive mode's "follow effect" on rowing machines. Identified limitations, including headset comfort and stability, alongside the need for audio considerations, underscore critical avenues for future AR hardware and interface development. This work confirms AR's considerable potential to redefine video consumption during cardio, emphasizing the necessity of tailoring design to specific machine contexts and individual user needs. We have provided design recommendations for future systems aiming to utilize AR to present visual media during exercise.

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A QUESTIONS

A.1 Pre-study

How often do you do cardio?

☐ Rarely or never (less than once a month)
☐ Occasionally (1–2 times per month)
☐ Moderately often (3-4 times per month)
☐ Often (1-2 times per week)
☐ Very often (3 or more times per week)

When you do cardio exercise, which of the following do you typically do at the same time? (Select all that apply)

☐ Listen to music or podcasts
☐ Watch TV shows or movies
☐ Watch short-form content (e.g., YouTube, TikTok, Instagram Reels)
☐ I don't do anything else while exercising
☐ Other (please specify): ____

Have you tried Augmented/ Virtual reality before? (Y/N): ______

In this study, I want to watch (Pick one only):

○ Brooklyn Nine-Nine
○ Family Guy
○ One Punch Man
○ Parks and Recreation
○ The Office

A.2 In-Between Viewing Modes Questionnaire

Participant number: ______
Machine Treadmill ☐ Elliptical ☐ Row ☐
Mode 1 ☐ 2 ☐ 3 ☐

What is your current rating of perceived exertion on a scale of 0 to 10? ______

Statement	Strongly disagree	Disagree	Slight disagree	Neutral	Slight Agree	Agree	Strongly agree
I found it cumbersome to watch the video	○	○	○	○	○	○	○
At higher intensities it got harder to watch the video	○	○	○	○	○	○	○
I found it enjoyable to watch the video	○	○	○	○	○	○	○
Watching the video enhanced my exercise experience	○	○	○	○	○	○	○

Any additional comments (write below)?

Please rank the three video viewing modes for the machine you have just exercised on :
1st place: 1 ☐ 2 ☐ 3 ☐
2nd place: 1 ☐ 2 ☐ 3 ☐
3rd place: 1 ☐ 2 ☐ 3 ☐
Any final comments (write below)?

A.3 Finishing Interview Questions

Now that you have experienced the three viewing modes on all machines, what is your overall ranking?

What did you think of the content selection? Did the content you picked have a notable influence on your enjoyment?

Please explain your viewing mode preferences on the different machines. What made a viewing mode work on one machine over another?

Describe the effect that having the video had on your workout. How did it differ between viewing modes?

How did the different levels of (workout) intensity affect your viewing experience?

Did you experience any issues on any of the viewing modes?

What makes a good viewing experience for you when doing cardio?

Anything that could improve the modes you experienced today?