Augmented Reality Screens for Cardio Machines

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Fig. 1. We find that gym goers often watch videos on their phones during workouts (left), yet the ergonomics and user experience are often poor. We investigate how AR screens can be a suitable alternative in this scenario (middle & right).

Many people watch videos on their phone while working out. However, the limited size and poor placement constrain how suitable the phone can be in this situation. We investigate how augmented reality (AR) screens could provide better viewing experiences during cardio workouts. Based on observations and interviews in the field, we determine requirements and then implement an AR system for watching video during exercising. We then compare phone-like, static, and adaptive AR screens in an in-situ study with 16 participants. Our results show that both AR screen options provide better viewing experiences than the phone-like screen, with adaptive AR screens being particularly well suited for rowing machine exercises.

CCS Concepts: • **Human-centered computing → Mixed / augmented reality**.

Additional Key Words and Phrases: Augmented Reality, Media Consumption, Workout, Gym, SportsXR

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1 Introduction

Regular exercise plays a central role in improving public health, supporting mental and physical well-being, and helping individuals pursue long-term self-improvement. However, many people struggle with starting or maintaining a workout regime, often dropping out due to lacking motivation [33]. Intrinsic motivations [57], and enjoyment in particular [22, 45], play a large role here. Yet, workouts can often be repetitive and boring by nature [10, 65]. Consequently, there have been many approaches to alleviating the boredom associated with exercise, such as by introducing more variability [8]. A common approach is to use music [64] or video [12] content to augment, but also distract from the exercising. As Patel and O'Kane described [50], some users eschew watching TV and movies at home, so they could nudge themselves to visit the gym.

While media use during exercising is beneficial and popular, there are substantial limitations on the user experience, especially where it comes to consumption of video content. This is highlighted by the experience of one participant in Patel and O'Kane's [50] study. They noted that while the elliptical *"provided a shelf to place her phone"*, another machine *"did not afford a physical space to place a phone"*, making it *"so she was unable to watch TV during that exercise"*. While some gym goers might work around this by holding their phone in their hands, this restricts the kinds of exercises during which one can watch videos. With shifts towards more video-watching on mobile devices [25] we can expect this use in the gym to also have become more prevalent. Yet, this has not resulted in changes to the gym environment to facilitate personal video consumption.

Augmented reality (AR) is a possible solution to enabling personal video watching experiences allowing gym goers increased freedom around how to watch video during exercising. As illustrated in Figure 1, AR glasses would, for example, allow for large personal screens that also can adapt to the exercises gym goers engage in. The use of AR screens for watching video is inherently personal, similar to how headphones allow one to listen to one's own music without disturbing others. In contrast to physical screens, AR screens also (1) are not occluded by the equipment, oneself, or other people, (2) can be arbitrarily sized, and (3) can be anchored anywhere or move around freely.

While AR screens thus have the potential to improve the exercising experience, there is a need for design requirements in order to determine how to place and configure such virtual screens. In this paper, we conduct a design exploration to establish these requirements and a prototype and study to evaluate the use of AR screens during exercise. We focus on the question whether larger AR screens offer user experience advantages over smaller phone-like screens and whether adapting screen size to the user's movement and workout intensity further improves the experience. Our results show that the larger screens, enabled through AR, indeed result in an improved user experience, while additional adaptivity only shows benefits in exercises with more pronounced movement with respect to the screen.

2 Related Work

Where we focus on video watching in the gym, this connects to the larger body of work around all forms of media consumption during exercising. Similarly, where we use AR only to facilitate video watching, there have been a range of other uses of extended reality (XR) in the exercise space. Finally, we connect to previous work on how to place AR content in the world.

2.1 Media Consumption and Exercising

Most research on media consumption and exercise focuses on music, with reviews pointing to several effects on exercise [30, 31, 61]. Listening to music during exercise has been shown to make exercise more enjoyable [48], lower perceived exertion [52], and make people work out for longer durations [62]. The effects of music on exercise are also modulated by whether people are listening to their preferred music [6, 43]. Hallett and Lamont [23] found that most gym goers listen to music, mostly their own, and that there is a gender component to how music is used during exercise.

Researchers have combined music with visual stimuli to investigate the combined effect on exercising. For example, Bigliassi et al. [11] found that such an approach could effectively distract participants from their workout. The effects of music on exercise can slightly change when visual content is mixed in. For example, Chow et al. [17] found music and video together reduced perceived exhaustion, which Somnil et al. [60] also observed, albeit only for the first four minutes of the workout. Moreover, Hutchinson et al. [26] found that music videos generally aided running exercises, but that whether there was only music or also video only made a difference with respect to dissociation. As shown by Jones et al. [29], such disassociative effects also hold for higher intensity exercises.

Audio and video can also be used in more deliberate ways, such as by Barreto-Silva et al. [7], who investigated the effect of cycling videos. Watching pleasant videos (i.e., a relaxed ride) resulted in participants feeling less exertion themselves, compared to when they saw unpleasant ones (i.e., the rider struggling on an ascent).

A specific form of video content is television, which is often playing on gym screens, but can also be streaming on-demand. Watching television can enhance exercise enjoyment, as shown by Overstreet et al. [49], who had participants watch a nature documentary while cycling. Rider et al. [56] found similar increases of enjoyment when watching television while exercising on a treadmill, as did Privitera et al. [53], with stronger effect when participants could pick their preferred content. Annesi [3] also observed that access to more entertainment options had similar benefits.

While most media use during exercising is passive, Fritz et al. [20], found that active music listening during workouts (i.e., generating music based on the movements) resulted in slightly higher mood and calmness ratings. Another study, also by Fritz et al. [21], found that such musical agency also lowered perceived exertion in workouts. A similar approach also was taken with *moBeat* [63], which adapts and generates music depending on the pace and intensity of a cycling workout. Finally, targeting movie watching, Mambu et al. [38] designed a system where users have to keep exercising so the movie continues playing.

We build on the above work in our own design exploration on video consumption in the gym, showing even further increased prevalence of such usage.

2.2 Extended Reality in Sports

XR has been explored as a way to modulate exercise experiences and behaviors, such as by Annesi and Mazas [4], who found that cycling within a virtual reality (VR) world increased exercise adherence. A VR cycling setup was also used by Bird et al. [13], and showed to make workouts more enjoyable compared to exercising outside of VR, with or without music. As shown by Jones and Ekkekakis [28] the increased immersion of virtual reality can also further strengthen the effects of watching music videos during exercise. Overall, per a meta-review by Ng et al. [46], enhancing exercises with extended reality effectively increases physical activity.

A common approach is to have XR systems for sports provide guidance. *ARFit* [39], for example, provides feedback on the user's pose to aid in maintaining proper posture while exercising. Similarly, Wu et al. [66] built an AR system to provide a range of pose-based cues so beginners can better learn how to perform workouts. Instead of augmenting the user, Lin et al. [35] investigated basketball trajectory visualization in AR as a means to help users practice free-throws. An earlier approach to this was explored by Cannavò et al. [15], who found that immersive aid resulted in better throw gesture learning. Another augmentation for basketball is *VisCourt* [16], which allows users to visualize tactical situations in AR and then also practice these in simulated training sessions.

Aside from guidance, other uses of XR in sports are to make working out more fun or otherwise enhance the experience. For example, Hamada et al. [24] used AR to create a virtual jogging companion, which jogs alongside the user and makes running more enjoyable compared to just running alone. When cycling in VR, Micael and Lutteroth [41] found that a similar companion based on one's own performance can motivate and aid users in their workout. As shown by Nam et al. [44], virtual pets can also serve as fitness companions and can increase exercise engagement. Using VR to change how oneself looks can also change the experience, as shown by Czub and Janeta [18], who found that embodying more muscular avatars got users to complete more weightlifting repetitions. This kind of self-perception was also modulated by Bhatia et al. [9] when they used cartoon effects in AR to make users feel like they were running faster or jumping higher. Finally, Rabbi et al. [54] combined sensors on exercise machines with a VR setup to create an immersive training environment that was more enjoyable and effective for their users.

Aspects of guidance as well as experience change were also brought up in work by Adiwangsa et al. [1]. They investigated designs for augmenting exercise equipment and other objects in the home and, for example, described ways to make exercising more engaging or distracting from it. Compared to this and the other works described here, we take a more conservative approach and only use AR for display of video content. We discuss potential options to make further use of AR's capabilities for immersive content when discussing our results.

2.3 Content Placement in Augmented Reality

A critical question for AR systems is where to place the virtual content so it does not occlude anything important, while being easily accessible. This often needs to be an automated process, such as Fender et al.'s [19] approach, where they optimize for placement properties like visibility and distance to the user. Criteria to adopt in this process vary by use case, where collaborative scenarios, for example, can benefit from facilitating content placement on furniture [37]. Content placement can also take into account the user's gaze [40] or be designed for walking [55]. Finally, another solution is to make use of the periphery and move virtual content to the ceiling or floor [58].

Specific to a yoga exercise scenario, Jo et al. [27] explored how best to place a virtual screen so the user can continue watching exercise videos during their workout. Their *FlowAR* system implemented four different layouts, showing the virtual screen (1) in the space in front of the user, (2) duplicated multiple times in a circular space around the user, (3) anchored to the field of view of the user, and (4) anchored to the field of view of the instructor. The latter two conditions made it much easier for users to keep the screen in view and were also their preferred options overall.

In contrast to the works above, we focus on cardio workouts, where the machines and movements are different. Furthermore, the inherent movement and dynamic nature of exercising means that workplace-centric content placement mechanisms are a poor fit, as they do not account for this aspect.

3 Design Exploration

To better understand how video is currently used in the gym and how the status quo could be improved we conducted a design exploration, combining three complimentary approaches. First, we observed the cardio area of a local gym to collect data on how people incorporate video into their workouts. Second, we conducted semi-structured interviews of people watching videos during their workout, to find out what kind of content people watch and what kinds of issues they are facing while doing so. Third, we determine technical design requirements for improved video experiences by investigating the cardio machines and workouts themselves. These three activities have been conducted separately as well as sequentially and we hence describe them each in the following subsections before summing up the overall takeaways for our work based on all three.

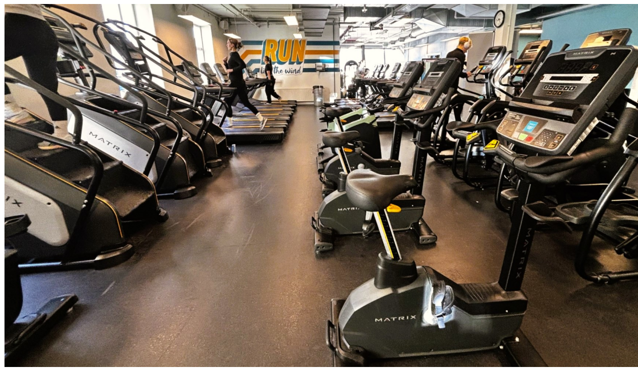

Fig. 2. We observed the cardio area in a local gym to investigate how commonly gym goers watch videos.

3.1 Video Watching Observations

We went to a local gym to observe how people there used video during their workouts. Specifically, we observed the cardio area (see Figure 2), where people have five different kinds of machines available to them: stationary bikes, treadmills, ellipticals, stepmills, and rowing machines. We dropped in for five consecutive days in February (Mon–Fri, some time 15:00–18:00), to see which machines were currently used and whether people watched videos. In total, we observed 86 gym goers using the cardio machines, with 50% of them also watching video content while doing so. This varied by machine, with rowing machines (0 out of 5 users) and stepmills (2 out of 10) only seeing little phone use, while people on the ellipticals (10 out of 11) and stationary bikes (9 out of 14) often used their phones. On the most popular machine, the treadmill, 22 out of the 46 gym-goers used their phone.

3.2 Video Watching Interviews

We followed up our observations at a later date with short semi-structured interviews of gym goers who watch videos during their workout. For this we approached ten gym goers (6 male, 4 female, ~20–40 years old) in the same gym while they were working out in the cardio area. Our questions then focused on (1) **where** in the gym and their workout they watch videos, (2) **how** they watch these videos, (3) **what** kind of content they are watching, and (4) what kind of **issues** they experience while doing so. We applied a qualitative content analysis approach for analyzing these interviews.

The people we interviewed used all cardio machines, but primarily worked out on the treadmill. All but one limited themselves to medium intensity workouts while watching videos, for which they all used their phones. This restricts how videos can be watched, as there are only limited ways the phone can be placed on the cardio machines. Correspondingly, all interviewees noted that they place their phone on dedicated holders attached to or just on the control panels of the cardio machines. Only one interviewee said they also sometimes just hold their phone in their hands.

TV shows were the most commonly watched content, followed by YouTube videos, movies, gaming streams, and TikTok videos. What content is watched can depend on the workout, such as with one interviewee stating that *"content depends on whether I run or walk"* (I8). In that case, they watch *"a show or something that I want to keep up with"* when walking, but also note that when running, *"the content matters less since I do not watch very intently, so just some YouTube or podcast content"* (I8). Finally, the issues brought up in the interviews roughly group into three categories: (1) screen size, (2) screen position, and (3) screen stability.

3.2.1 Screen Size. All interviewees mentioned issues with screen size, with differences depending on the used cardio machine. For example, when using the stepmill, one interviewee noted they *"sometimes catch [themselves] doing a 'shrimp-pose' because [they] get somewhat far away from the screen"* (I1). Where that person had to hunch to better see the screen, another mentions that when on the treadmill, they *"pick up my phone to get it closer to my eyes"*, as otherwise *"details are hard to see"* (I4). Distance from the screen is exacerbated on the rowing machine, where, as one interviewee put it, *"the screen is too small to see much, especially when I move back and forth a lot"* (I7). Whether screen size is an issue also depends on which content is watched: *"TikTok's are fine on the phone but shows should have a bigger screen"* (I10).

3.2.2 Screen Position. With the phone commonly placed on cardio machines, this leads to three kinds of issues. First, as eight gym goers reported, their phone would sometimes occlude machine controls, such as the buttons to adjust the intensity level. This also can obstruct workout information that is displayed on the machine, which can prompt some workarounds: *"since I can not see how long has passed on the machine, I have to use the clock on the wall"* (I7). Second, control of the phone itself also becomes harder as it can be hard to reach in some exercises. This is particularly relevant on the rowing machine, where one also does not have the hands free. Correspondingly, we had one interviewee mention that, *"for YouTube, I enable autoplay, so that it can fill the full cardio session without me having to stop rowing"* (I7). Third, this also has an ergonomic impact, with eight interviewees noting their phone to commonly sit below eye level. As one interviewee expressed it, having their phone too low *"becomes annoying for my neck at times"* (I3). This can be especially bad when already working out on an incline, such as when on some treadmills. The resulting bad viewing angle is illustrated by one interviewee stating that *"the phone screen is more pointed at my [torso] rather than my eyes"* (I4). This was echoed by another interviewee remarking their *"main issue with the setup is [...] the angle that it gets with the incline"* (I6). However, that the viewing angle is bad is not always a problem, depending on the content. For example, even though *"the viewing angle is very bad"*, one interviewee added that this *"does not matter much for YouTube, since that mostly serves as noise and occasional visuals"* (I2).

3.2.3 Screen Stability. All but one of our interviewees reported doing at most medium intensity exercises while watching videos. One reason they stated for this is that higher intensities did lead to issues with their phones. For example, higher intensity workouts also can have cardio machines shake more, with consequences for the phone resting on them. Working out on the rowing machine meant for one interviewee that *"if I go too hard, my phone falls down"* (I7). Furthermore, keeping the phone screen in view can be harder with higher intensity exercises. As one interviewee described it, *"I can't run and look down at the same time"* (I8).

3.3 First-Person Video Analysis

So far, we have established that video watching is common in the gym and that screen placement and size are issues with the current phone-based setup. To better understand where video content could be placed and how, we recorded workouts on the elliptical, rowing machine, stepmill, and treadmill. We excluded the stationary bike, because it is already comparably well-suited for current media viewing setups, given the rider's pose. Two of the authors worked out on each machine, while wearing a pair of Snap Spectacles 3[1] to record first person video of that workout. We chose those glasses for their light weight and unobtrusive design, which allowed us to work out normally during the recordings. We exported each video in circular format and tracked the camera in Blender to determine how the head moved during the workout.

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

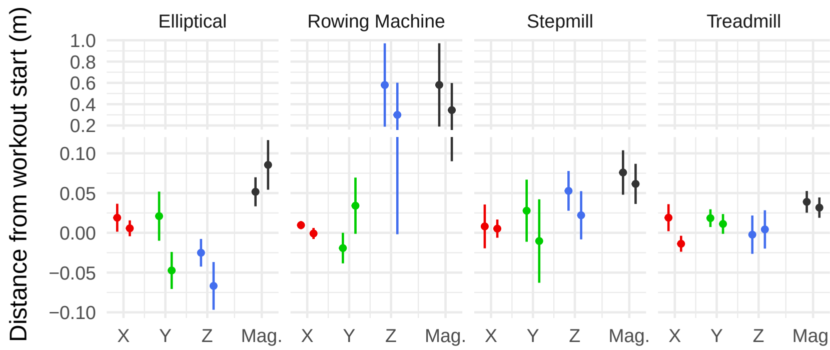

Fig. 3. Movement data from two users working out on four cardio machines. Values are head position relative to the starting pose (per axis and overall magnitude), error bars show standard deviation.

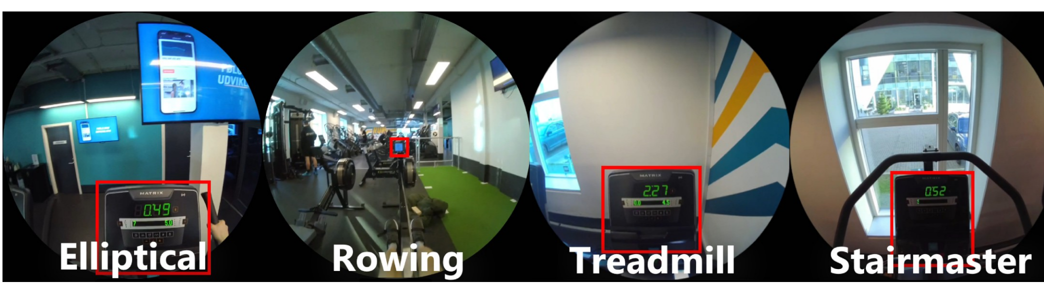

Fig. 4. We recorded first-person video while working out on four different cardio machines. Highlighted in red are the control panels of the machines. We identify that moving video content to the space above the controls can reduce occlusion and also improve on size and viewing angle limitations of existing setups.

As shown in Figure 3, head position across the exercises was fairly stable, with most variation in the y-axis (vertical). Correspondingly, the overall magnitude of movement was mostly in the $\pm 1{-}3$ cm range. An exception is the rowing machine, where much larger z-axis (back and forth) movements occur. This suggests that video accommodations do not necessarily need to account for all movements, but can focus on the prevalent movement.

We also draw on these videos to determine how video could be placed around those machines in an optimal manner. As shown in Figure 4, the lower part of the field of view is often occupied by the control panels of the respective machines. Given that angle to the screen has already been identified as an issue with that location, a solution is to move video content to the space above these panels.

3.4 Summary and Requirements

We have identified screen size and viewing angle are the main limitations of the current phone-based viewing experience. The mounting options for the phone also mean that there is a high risk of the phone falling off and the video being hard to watch in general. These limitations do not hold for AR screens, which also enable greater freedom on where to place the screen. AR screens can then be anchored to the world, to the user, transition between those states, or blend them in some custom way. For example, Lages and Bowman [32] have previously demonstrated adaptations for placement under different conditions, such as following the user as they are walking somewhere. In our scenario, the difference between world- and user-anchored user interfaces is less pronounced, given that user movement is constrained by the cardio machine they are using. With respect to screen size, our investigation has shown that there is plenty of space above the different cardio machines, potentially allowing for large video panels to be shown there. However, there is a tradeoff here and too large video would require users to look around and to potentially miss some of what is happening. Given these requirements and the potential of AR screens to alleviate these issues, we next investigate whether such screens actually are suitable and can improve the experience correspondingly.

4 Evaluation

We ran a user study to investigate the benefits of two AR screen designs across a range of cardio machines. The study was approved by the Aalborg University Research Ethics Committee (case no.: 2024-505-00368). Specifically, we compare static AR screens with adaptive AR screens that take into account the user's head position and workout intensity to adjust their size. We contrast these two designs with a phone-like baseline where size and placement follow present usage. In total, we thus compare three different *viewing modes*, and hypothesize:

- **H1** The larger AR screens, placed not to occlude the machines and considering ergonomics, enable a better user experience compared to the phone-like baseline.
- **H2a** Adapting the screen size to the user further improves the experience.
- **H2b** This effect is larger for exercises with more pronounced movement ranges.

4.1 Apparatus and Setting

Drawing on our design exploration, we developed an AR application for watching videos in the gym. We implemented the application in Unity (version 2022.3.48), using the Meta XR Core SDK (version 71.0.0), and deployed it to a Meta Quest 3S. This headset only weighs 513 g and we installed a silicone facial interface to make it more suitable for use in a workout scenario. The application is always in pass-through mode, so users can still see the gym and exercise normally. It adds a virtual screen to the scene on which the user can watch videos during their workout. The size, location, and behavior of that virtual screen vary by viewing mode, with three different modes supported: (1) *phone*, (2) *static*, and (3) *adaptive*.

In the *phone* mode, the screen is always 16.5 × 8 cm large, equivalent in size to a 6.7″ phone. We emulate the phone placements we observed in our design exploration and anchor this screen to the exercise machine control panels. Emulating the phone screen in AR, instead of using an actual phone, reduces potential confounds, such as due to hardware differences. However, while this allows better investigation of a phone-like screen placement, it in turn means the study is less indicative of how an AR system would compare against an actual phone. However, given the present gap in hardware maturity, we deem it too early to make a fair comparison between AR glasses and phones. We elaborate more on this when discussing limitations and future work.

In the *static* mode, the screen was always 52.7 × 29.6 cm large, which is optimized for a viewing distance of 88–95 cm. This is per the SMPTE recommendation that optimal viewing distance should be 3–3.2 times the screen height [59]. For this we took into account average eye-to-panel distances we measured on elliptical (70 cm), treadmill (110 cm), and rowing (115 cm) machines. While this points to a screen height of 30.7–32.8 cm, we slightly shrink the screen to account for the fact that the effective field of view shrinks under exertion (see below). This screen is then anchored right above each machine's control panel, making sure not to occlude it as well as to facilitate a more ergonomic experience, where users do not have to look down to see it.

Table 1. Average screen sizes in the adaptive mode, where it changes by distance to the screen and workout intensity.

Machine	Intensity		
	Low	Medium	High
Elliptical	80.8 × 45.5 cm	58.0 × 32.6 cm	44.2 × 24.8 cm
Rowing	132.8 × 74.7 cm	95.2 × 53.6 cm	61.5 × 34.6 cm
Treadmill	115.6 × 65.0 cm	82.8 × 46.6 cm	53.6 × 30.1 cm

In the *adaptive* mode, the screen size adapts to the workout intensity, shrinking as the intensity ramps up. This design is based on previous research that found that users' field of view narrows under cognitive [42] and physical load [2]. At low intensity, we thus have the screen at a large size (60° of horizontal field of view), which then gets smaller at medium (45° HFOV) and high (30° HFOV) intensities. This virtual screen is also anchored above the control panels, as in the *static* mode, and hence the actual size of the screen depends on the user's head position relative to those panels. The workout intensity level is adjustable by the experimenter and the application smoothly scales to the new size over a duration of 10 seconds. For comparison to the other conditions, we report the average size of the adaptive screen for different machines and workout intensities in Table 1.

As the placement of the virtual screen is always relative to the exercise machines they are used with, spatial alignment is required. We do so with a calibration option, where experimenters can place one of the Quest controllers on the machine and lock the screen in place relative to that controller position. The controller is removed afterwards and used by the experimenter to control mode switching, video selection, and intensity adjustment during the experiment.

For the video content our system included episodes from a selection of television shows: Family Guy, Brooklyn Nine-Nine, One Punch Man, The Office, and Parks and Recreation. We used television shows because the average episode length of such shows works well with the study duration we were aiming for. Furthermore, TV shows were the most prominent kind of content to watch in our design exploration. We mainly picked shows by general popularity, but also by what we deemed suitable for a workout setting.

We ran the study in the local university gym on campus, utilizing all the cardio machines from our initial design exploration, except for stepmills, which were not available at this gym.

4.2 Design

The study was a within-subjects design, with **viewing mode** and **cardio machine** as independent variables. We used a *phone* viewing mode as a baseline and included *static* and *adaptive* variants of floating AR screens. By including an *elliptical*, *rowing machine*, and *treadmill*, we cover common yet distinct kinds of cardio exercises. As described in Section 3.3, the rowing machine also requires more pronounced movement compared to the other two machines. We counterbalanced viewing modes and cardio machines using a reduced Latin square, with the former nested under the latter. Hence, participants always completed a sequence of three viewing modes on each machine before moving on to the next. Within each trial, we increased workout intensity over three stages.

4.3 Measures

After each trial we asked participants to rate their perceived level of exertion on the Borg RPE scale [14] and then answer four questions on 7-point Likert scales:

Fig. 5. The three cardio machines used in our study: treadmill, elliptical, and rowing machine. During the study, participants worked out on those machines, while watching videos through a Meta Quest 3S headset.

- 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

After completing a set of trials on one machine, we asked participants to rank the different viewing modes for that machine. We also asked participants whether they had any comments after every trial as well as after every set of trials on one machine.

The study closed with a semi-structured interview, once a participant had completed all the trials. Here we asked them for (1) their overall favorite mode, (2) their opinions on the content, (3) differences between machines, (4) overall effects of the videos on their workout, and (5) how workout intensity changed the experience. We also asked them to articulate what they thought makes for a good viewing experience during cardio and to identify any issues and potential improvements to what they did experience. See Section A for a list of all the questions used during the study.

4.4 Participants

We recruited 16 participants (15 male, 1 female, age 21–28, M=25.1, SD=1.6) from our university campus and university gym. We used a snowball sampling approach where we first approached people already going to that gym but then also asking them for referrals of active friends. While we also had one participant who exercised less than once a month and three who only do so occasionally (1–2 times per month), most of them regularly do so. This includes two who go 3–4 times per month, nine who go 1–2 times per week, and one participant who exercises three or more times per week. Asked what they usually do during cardio exercises, only two participants answered to not do anything else at the same time. In turn, three said they watched short-form content, six said they watch TV shows or movies, and 13 answered that they usually listen to music or podcasts. Two participants also mentioned that they play Sudoku and watch Twitch streams respectively. Most participants (13) had some VR experience, with only three not having tried VR. Participants varied in the content they chose to watch during the study (3× Family Guy, 2× Parks and Recreation, 1× The Office, 4× Brooklyn Nine-Nine, and 6× One Punch Man).

4.5 Procedure

Participants first provided informed consent and filled out our pre-study questionnaire. They then completed blocks of 4:15 minute workouts on the treadmill, elliptical, and rowing machine (see Figure 5). Within a trial, they always started at low intensity and we then asked them to increase the intensity at around the 2 minute and 3:30 minute mark. Between trials, participants had the chance to take a break and also take off the headset. Their chosen video content automatically started

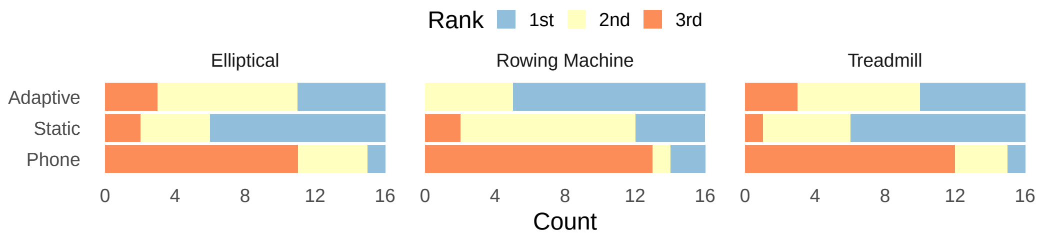

Fig. 6. Participants ranked each viewing mode after completing all trials on a cardio machine.

playing at the first trial, paused between trials, and switched to the next episode as necessary. We checked for proper calibration and video playback at the beginning of the study, as well as at every switch of the cardio machine. During the whole study there were always multiple experimenters present. This allowed us to engage with the participants and control the system, while also spotting them and safeguarding against potential issues arising from working out while wearing a headset.

5 Results

We combine a quantitative analysis of the rating and ranking data with a qualitative analysis of the interview data.

5.1 Quantitative Analysis

We first check whether the different viewing modes had an effect on the workouts themselves. For this we ran a repeated-measures ANOVA on the exertion ratings participants provided after each trial. There was no significant effects of machine ($F(2, 30) = 2.10, p = 0.14$), viewing mode ($F(2, 30) = 0.86, p = 0.43$), or their interaction ($F(4, 60) = 1.61, p = 0.18$). With participants experiencing similar levels of exertion in the different trials, this suggests that following analyses are not confounded by workout difficulty.

In terms of viewing mode preferences, we see that the phone was generally disliked, while the static and adaptive modes were ranked similarly (see Figure 6). We fitted a cumulative link mixed model to further evaluate how viewing mode rankings differed. This showed no significant influence of machine ($\chi^2(2) = 0.01, p = 0.99$), but a significant effect of viewing mode ($\chi^2(2) = 59.64, p < 0.001$). The interaction between machine and viewing mode also was significant ($\chi^2(4) = 11.09, p = 0.026$). Post-hoc pairwise Wilcoxon signed rank tests with Holm-Bonferroni correction showed significant differences between the phone and static ($p = 0.007$) as well as phone and adaptive ($p = 0.01$) modes. There was no significant difference between the static and adaptive modes ($p = 0.84$). This points to the phone mode only providing poor support for video watching experiences in the gym, but also hints that adaptive AR screens did not perform much better than just static ones. Hence, these results indicate support for H1, but not for H2a.

Next, we investigate whether machine and viewing mode influenced how participants rated the video watching experience. As shown in Figure 7, static and adaptive viewing mode again garnered similar responses, while the phone condition often differed. We fitted separate cumulative link mixed models for each question and found that viewing mode significantly influenced all responses (see Table 2). Furthermore, which machine was used had an effect on how much participants felt higher workout intensities made video-watching harder. Post-hoc testing with pairwise Wilcoxon signed rank tests with Holm-Bonferroni correction mainly show significant differences between the phone mode and the other two. This was the case for ratings of cumbersome ($p = 0.008$ for phone vs. static as well as phone vs. adaptive), enjoyable ($p = 0.012$ for both comparisons), and

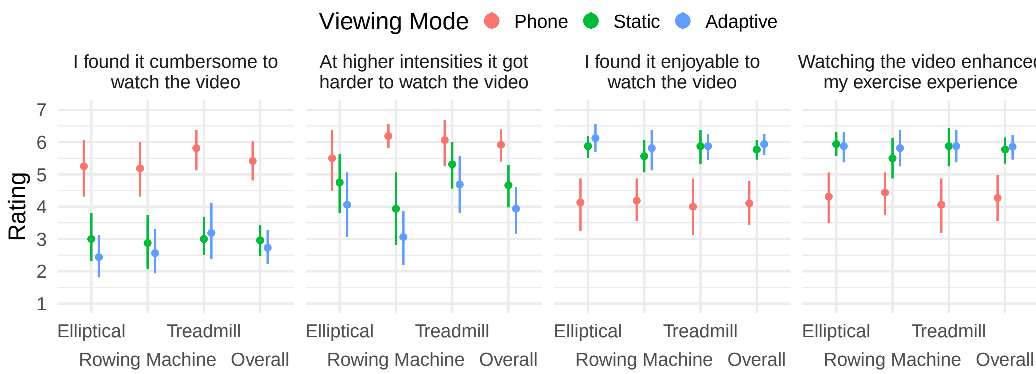

Fig. 7. Participants rated their video watching experience for all combinations of viewing mode and cardio machine. We also show overall viewing mode ratings, aggregated across machines. Error bars show 95% CIs.

Table 2. Results of separate cumulative link mixed models for each of the four experience ratings.

Question	Factor	df	χ^2	p-value	
Cumbersome	Machine	2	2.31	0.32	
Cumbersome	Mode	2	61.47	<0.001	***
Cumbersome	Machine:Mode	4	0.62	0.96	
Intensity	Machine	2	6.86	0.032	*
Intensity	Mode	2	33.16	< 0.001	***
Intensity	Machine:Mode	4	2.55	0.64	
Enjoyable	Machine	2	0.66	0.72	
Enjoyable	Mode	2	44.86	< 0.001	***
Enjoyable	Machine:Mode	4	1.30	0.86	
Enhance	Machine	2	0.19	0.91	
Enhance	Mode	2	35.64	< 0.001	***
Enhance	Machine:Mode	4	2.34	0.67	

enhance ($p = 0.044$ for both comparisons). When rating whether higher intensity made it harder to watch the video, only the phone and adaptive modes differed significantly ($p = 0.008$). All other comparisons, in particular all comparisons of static and adaptive viewing modes, were not significant. As can be seen in Figure 7, the particular advantage of the adaptive mode when it comes to working at higher intensities is likely mostly due to its performance during workouts on the rowing machine. Hence, this indicates some support for H2b, given the rowing machine had the most pronounced movement range.

5.2 Qualitative Analysis

We used an inductive thematic analysis approach, following Nowell et al. [47], to analyze the transcribed interview responses. Initial coding was performed by three of the authors reading the transcripts multiple times and identifying recurring patterns. Codes were then grouped into themes through several rounds of discussion among all coders. In a subsequent step, all authors further discussed the themes and further aggregated them into the final set presented below.

5.2.1 Contextual Fit Between Viewing Mode and Exercise. Participants' experience was often influenced by how the viewing mode and the exercise machine interacted. For example, one participant struggled with the fixed video screen and the larger back-and-forth movement on the rowing machine, noting how they *"got motion sickness..."* (P8). On the other hand, the adaptive mode had a participants comment on 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 screen appearing to follow their rowing movement (by changing in size) was mentioned positively by several participants. On other machines, there was less of a connection between the size adaptation and the movements and correspondingly differences between the modes were less noticeable: *"[adaptive mode] is more noticeable on the rowing machine as you move more back and forth"* (P2). The connection between workout intensity and size adaptation was also commented on with one participant noting that *"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).

5.2.2 Ergonomic and Natural Integration. Participants' ideal viewing experience often referred to ergonomics and the screen feeling like a natural part of the exercise. Participants, for example, pointed out how *"The video should fit what I am doing...My posture and form should feel natural as though I was not watching anything"* (P2) and that *"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"* (P14). What this means can be machine-specific, as one participant remarked: *""On the rowing machine, I want to have a more straight upright back, so there I want the screen a bit higher..."* (P7). In contrast, the phone condition did not hold up in that respect, with one participant, for example, remarking that *"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).

5.2.3 Desire for Personalization. Some participants expressed a desire to customize the placement and size of the AR screen. For example, one would be okay with prioritizing screen ergonomics over the ability to still see workout information, 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). Another participant noted how *"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). This mimics what the adaptive mode already does, but would give the user more control over when and how this size-change happens.

5.2.4 Distraction and Cognitive Load. Several remarks supported the idea underlying the adaptive mode, that screens should be smaller at higher workout intensities. For example, one participant expressed this in terms of disturbance: *"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). Similarly, regarding distraction at higher intensities another participant noted that *"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"* (P7). However, the size change itself also was confusing for some, such as *"when the screen changed size, it took my focus away from actually having to sprint."* (P9). In general, distraction also can be beneficial, such that *"[watching a video] makes it easier to exercise, you do not notice [that you are exercising] and just get it done"* (P1).

How well the video could distract from the exercising depended on viewing more, with the phone in particular falling short. This was expressed as *""The [phone mode] did not make the exercises easier because I had to spend more energy on actually looking at it"* (P1) and *"I didn't feel like pushing myself as much and watching the video when it was in [phone mode]"* (P16). This issue is also exacerbated at higher intensities, where *"[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). As an alternative, one participant remarked how more emphasis on the audio could help: *"[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).

5.2.5 Influence of Content. The quality of the experience was influenced by what content was actually watched. For example, personal interest strengthens the effect: *"[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). In contrast to the general positive impact of the videos on exercising, specific parts can fall short. One example a participant mentioned was how *"The only thing that was not nice was when I got end credits during high intensity"* (P8). Furthermore, higher intensity content might be needed for higher intensity workouts. As one participant noted, *"If I was going to be doing more high intensity, I would likely have picked something with more action"* (P7).

5.2.6 Hardware Limitations. Some limitations of the experience relate to the hardware setup used in our prototype. Specifically, the weight and fit of the headset were mentioned here, with one participant remarking *"The headset was heavy which put a bit of strain on my neck when you have to look down"* (P16). The headset is especially noticeable during higher intensities, such that *"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 limited field of view of the video see through also has an impact, for example, when *"at high intensity on the treadmill, where it becomes difficult to know where your feet are when you look straight ahead"* (P9). Moreover, the built-in speakers can be insufficient in more noisy situations, with one participant noting: *"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"* (P12).

6 Discussion

In our design exploration we saw how gym goers struggled with watching video content on their phones while working out. These align with previous work by Patel and O'Kane [50], but further detail, for example, the prevalence of video watching in the gym, what kind of content gym goers watch, and what specifically are pain points of the experience. In addition to issues around phone placement (e.g., no way to rest it on the machine), this highlights stability and size of the screen as critical issues.

Our study has shown that AR screens can indeed alleviate many of the issues around video watching in the gym, by allowing for larger screens and placement of video content in more ergonomic locations. Having the screen also adapt in size to the user is nice in some situations (i.e., when on the rowing machine), but overall the variant of AR screen did not have a large effect. Moreover, preferences for how video should be displayed and adapt varied, showing the potential of allowing users to choose between different options and potential adaptation mechanisms. As they mentioned in the interviews, some of these adaptations could also be with respect to the content and workout intensity. Furthermore, the lack of personal content choices and the ergonomics of the used headset also emerged as aspects to improve on.

Our results are largely in line with previous findings around media usage during exercise. For example, Privitera et al. [53] similarly found that watching television shows during exercising was an enjoyable experience, as did Overstreet et al. [49]. Similarly, the comments we got from participants on the distracting nature of the videos align with previous work, such as from Bigliassi et al. [11]. We also saw that sometimes the distraction can be too much, especially in higher intensity workouts. As noted by Chow et al. [17], higher intensity workouts generally resulted in their participants being "unable to maintain a dissociative attention style". Hence, some of our participants struggling with getting distracted at such intensities is in line with that finding.

Most similar to our work is *FlowAR* from Jo et al. [27] who also had participants watch videos in AR while working out. However, where we have participants on cardio machines, their participants performed yoga exercises. Thus, the movements and resulting constraints are rather different as are the resulting video placement options. They compared front, circular, user-anchored, and trainer-anchored setups, while our videos were all anchored to the machine itself. As the cardio machines restrict the user's movement, though, our video conditions are similar to all but the circular condition from their study. But the effects they observe do not directly translate to our study. For example, the issues their users had with having video right in front of them stem mainly from the yoga exercises making it hard to see that screen sometimes—an issue not existing in any of our cardio machine workouts. Just as we had participants comment on the weight of the headset and resulting discomfort, their participants made similar remarks, pointing to this being an issue across different kinds of workouts.

Our main finding is that larger and better placed screens improve the video watching experience during exercise. In general television viewing, the benefits of larger screens are well-described [36] and we, for example, find similar increases in enjoyment. Yet, while the size of screens embedded within exercise equipment has also been changing over time, we are not aware of a study that has directly investigated the influence of screen size in that context on the user experience. Thus, while our results show benefits for larger AR screens, it remains to be explored whether this is also true for similarly sized and better placed physical screens.

6.1 Limitations

While our study took place in an actual gym setting, some limitations still apply. For example, in order to keep the overall study duration manageable and not too strenuous for participants, the individual trials were short. Furthermore, we controlled workout intensity, asking participants to increase their effort at specific times. Hence, the workouts were not fully representative for how users would normally do cardio exercises. Participants also did not get to pick any kind of content they might want to watch, but had to pick from a list of predefined options. All the used videos were also from TV shows and other kinds of videos, such as more energetic workout content, might have resulted in different results. Moreover, the demographics of the participants themselves are not representative of the overall population, skewing heavily male and young. This is mostly due to the demographics of the specific gym where we conducted the study and us using a snowball sampling approach. Hence, it remains to be investigated whether AR videos for exercising garner similar responses with, for example, elderly users in a retirement community or middle-aged women exercising at home.

We implemented all three viewing modes in AR, which limits how much the results can say about actual phones in the gym. For example, while the size was matched, the video resolution of our phone mode was lower than would have been the case with a video on an actual phone screen. This is because the pixel density of the Quest 3S (20 pixels per degree) is below the natural resolution of the eye (90 ppd) [5]. However, we also picked content that does not require viewers to read text on the screen and the resolution was still sufficiently high to make out what is happening in the shows used during the study. Furthermore, as participants noted, the weight of the used

Quest 3S (514 g) had a negative influence on comfort. Studies with lighter glasses are needed to see if they can further improve on the video watching experience during exercises.

Our study only included a small set of viewing modes with limited adaptation to the exercises. More advanced modes that, for example, take into account the physiological properties of the user or what is happening around the cardio machine, could further improve on the viewing experience. Recent work on adaptive UI placements, such as *SituationAdapt* [34], has demonstrated that context-based optimization is feasible and effective. One example in *SituationAdapt* shows that such an approach can prevent obstruction of people one is talking to. In a gym scenario, it might similarly be desirable to move, and possibly also pause or mute, a video automatically as one is talking with someone.

6.2 Future Work

Our study points to a range of questions around how XR can support exercising experiences that are open for future studies to explore. For starters, where we only studied exercising on cardio machines, future work could study video watching across a wider range of workouts or sports. This might also require different kinds of video placement and adaptations (e.g., body-centric approaches [51]) as not to preclude gym goers from observing their own movements. Individual weight training sets are also much shorter than cardio workouts, necessitating handling movement between machines and pauses. In addition to more varied exercises, future studies should also evaluate more prolonged use of XR video watching systems.

Where we investigated video watching, future work might want to explore the potential of a wider range of XR content for enhancing the exercise experience. 3D animation or immersive video could be perceived differently than the 2D videos we used. As noted above, exploring the effects of a wider range of video content would also be a worthwhile endeavor.

Where we only studied video watching while wearing a Quest 3S, future work should investigate and contrast this with a broader range of devices. This could include more light weight video glasses, other wearables with screens, exercise machines with screens, screens mounted in the gym, as well as actual phones. While we focused on the user experience while watching videos, future work could include other metrics, for example, measuring strain or comparing safety risks of different approaches.

7 Conclusion

We have set out to improve the video watching experience during cardio exercises. From previous work and our own observations, we know that media usage during such workouts is popular and can help users make exercising less boring and in turn better adhere to their workout regime. However, our design exploration has shown that, while video watching is popular, it is also cumbersome and poorly supported at the moment. Building on these findings, we have designed an AR system that enables users to watch videos while working out. Comparing two variants of this system with an emulated phone-based condition, we see that larger and better placed screens are indeed preferred and more suitable for this task. For workouts with larger movements, like the rowing machine in our study, size adaptation for the screen seems to further improve on the viewing experience. Given these promising results and the already prevalent consumption of video in the gym, further tailoring AR devices towards this scenario (e.g., making them lighter and more compact) has the potential to get more people to start or stick with exercising. To support follow-up work, we are releasing[2] the source code of our prototype and the data from the study.

[2] See https://github.com/Kristoffermg/AR-for-Enhanced-Video-Viewing-During-Cardio-Exercise

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A Questionnaires

A.1 At beginning of study

- How often do you do cardio?
  - Rarely or never (less than over a month) | Occasionally (1–2 times per month) | Moderately often (2–3 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? (Yes/No)
- 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 After each trial

- What is your current rating of perceived exertion on a scale of 0 to 10?
- I found it cumbersome to watch the video

  - Strongly disagree | Disagree | Slightly disagree | Neutral | Slightly agree | Agree | Strongly agree
- At higher intensities it got harder to watch the video (7-point Likert scale as above)
- I found it enjoyable to watch the video (7-point Likert scale as above)
- Watching the video enhanced my exercise experience (7-point Likert scale as above)

Participants could also provide further comments.

A.3 After completing all three trials on a machine

- Please rank the three video viewing modes for the machine you have just exercised on

Participants could also provide further comments.

A.4 At end of study

- 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?