



Exploring Opportunities for Augmenting Homes to Support Exercising

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探索增强家庭环境以提供支撑的机遇 锻炼

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你好，这个问题我无法回答。
很抱歉不能帮助你。

您的问题我无法回答。
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ABSTRACT

Although exercising at home has benefits, it is not always engaging or motivating. Augmented Reality (AR) head-mounted displays (HMDs) offer the potential to make in-home exercising and exergaming more inclusive and immersive, but there is limited research investigating how such systems can be designed. We employed a participatory design approach involving semi-structured interviews to investigate how homes can be augmented to facilitate exercising experiences. We developed 10 recommendations for developing home-based exercising experiences using AR HMDs. Our results further contribute to the existing body of research on the use of AR for exercising, home applications, and everyday objects by presenting the first foundational study investigating the wide range of exercises that can be supported through AR HMDs in home environments and the different ways home elements may support these exercises, and laying the groundwork for future work developing home-based exergaming through AR HMDs to increase people's physical activity levels.

CCS CONCEPTS

- Software and its engineering → Interactive games; • Applied computing → Computer games; • Human-centered computing → Participatory design; Mixed / augmented reality.

KEYWORDS

Augmented reality, Exercising, Exergaming, Home environment, Participatory Design

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1 INTRODUCTION

Exercising can improve energy levels, quality of life, and mental well-being [24, 36, 37]. However, exercise is difficult to start, and even harder to maintain, with many people not getting enough exercise. A survey conducted in 100 cities in America found that only 40% of female and 57% of male adolescents complied with the national physical activity guidelines [12]. Regular exercise requires discipline, but exercise routine can be repetitive, causing people to lose motivation and stop exercising [4, 29]. In addition, lack of time or proximity to exercise facilities can reduce physical activity [4, 18], while unexpected external circumstances (e.g., COVID-19 lockdowns) can disrupt exercise routines [19, 41]. Financial, cultural, or personal reasons can also affect willingness to exercise [21, 28, 35, 46], such as the cost of gym membership or home exercise equipment, lack of separation between men and women in exercise facilities, feelings of embarrassment from exercising in front of others, or medical conditions. Exercising at home can enable people to overcome these barriers, as they do not need to commute or have nearby facilities, with the option to continue exercising during unexpected or personal circumstances. However, exercising at home is not always engaging or motivating, and therefore the effectiveness of home-based exercises usually depends on individual adherence and commitment to following the exercise routine [13, 34].

Exercise video games (exergames) have been used to increase physical activity levels at home. An exergame is defined as “a video game that promotes (either via using or requiring) players’ physical movements (exertion) that is generally more than sedentary and includes strength, balance, and flexibility activities” [44]. Sween et al. [58] conducted a literature review of previous studies that investigated the impact of active video game(s) or exergaming on energy expenditure (EE) levels. Based on a review of 27 studies, they found that exergaming can increase EE to levels that meet the American College of Sports Medicine (ASCM) recommended guidelines for health and fitness (≥ 150 min/week of moderate intensity), up to 300% above resting level. As most of the studies reviewed were conducted in lab-based settings, Sween et al. [58] also argued that the increase in EE levels could be even higher in a home environment where people spend a longer time playing video games. An important determinant of the amount of time allocated to an activity is the perceived enjoyment of the activity [38]. Because exergaming has been shown as an enjoyable activity

摘要

尽管在家锻炼具有诸多益处，但它并不总是吸引人或激励人。增强现实（AR）头戴式显示器（HMDs）为提升居家锻炼和运动游戏的包容性与沉浸感提供了潜力，但关于此类系统设计方式的研究仍十分有限。我们采用参与式设计方法，通过半结构化访谈探究如何通过增强家庭环境来优化锻炼体验。我们提出了10项建议，用于开发基于AR HMDs的居家锻炼体验。我们的研究结果进一步拓展了AR在锻炼、家庭应用及日常物品使用领域的现有研究：首次通过基础性研究系统探索了AR HMDs在家庭环境中可支持的各种锻炼形式，分析了不同家庭元素对这些活动的支撑方式，并为未来开发基于AR HMDs的居家运动游戏以提升人们身体活动水平奠定了基础。

CCS概念

• 软件及其工程 → 互动游戏; • 应用计算 → 电脑游戏; • 以人为中心的计算 → 参与式设计; 混合/增强现实。

关键词

增强现实, 锻炼, 运动游戏, 家庭环境,
参与式设计

ACM参考格式:

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1 引言

锻炼可以提升能量等级、生活质量以及精神状态。幸福感[24, 36, 37]。然而，开始锻炼并非易事，坚持锻炼则更加困难，许多人未能进行足够的体育活动。一项在美国100个城市开展的调查显示，仅有40%的女性和57%的男性青少年符合国家体育活动指南[12]的要求。定期锻炼需要自律，但锻炼计划可能重复单调，导致

人们失去动机并停止锻炼[4, 29]。此外，缺乏时间或锻炼设施的邻近性会减少身体活动[4, 18]，而意外的外部情况（例如，新冠肺炎封锁）可能打乱锻炼习惯[19, 41]。财务、文化或个人原因也会影响锻炼意愿

[21, 28, 35, 46]，例如健身房会员费用或家用锻炼设备、锻炼设施中缺乏男女分开的配置、在他人面前锻炼产生的尴尬感，或医疗状况。在家锻炼

能帮助人们克服这些障碍，因为他们不需要通勤或依赖附近设施，并可在意外或个人情况下继续锻炼。然而，在家锻炼并不总是吸引人或激励人，因此居家锻炼的效果通常取决于个人坚持和遵循锻炼计划[13, 34]。

运动视频游戏（运动游戏）已被用于提升在家时的身体活动水平。运动游戏被定义为“一种通过使用或要求玩家进行身体运动（运动量）的视频游戏，其运动量通常超过久坐行为，并包含力量、平衡和灵活性活动”[44]。斯温等人[58]对先前研究的文献综述进行了梳理，这些研究研究了主动视频游戏或运动游戏对能量消耗（EE）等级的影响。基于对27项研究的回顾，他们发现运动游戏可以将EE提升至符合美国运动医学学院（ASCM）建议的健康与健身指南的水平（ ≥ 150 分钟/周的中等强度），最高可达静息水平的300%。由于大多数研究所审查的研究均在实验室环境中进行，斯温等人[58]还提出，在家庭环境中能量消耗水平的提升可能更为显著，因为人们会花更长时间玩视频游戏决定活动时间分配的重要因素是对该活动的感知享受程度[38]。由于运动游戏已被证明是一项愉快的活动

for multiple age groups, it has the potential for sustained activity (exercise) participation [38]. Exergaming can promote physical activity, especially for people who are less motivated by traditional exercising [38]. However, popular exergaming systems are not always safe or inclusive, especially for some groups of people. For example, the Nintendo Wii handheld controller and balance board are unsuitable for people with motor limitations such as tremors (e.g., people with Parkinson Disease (PD) [45]) due to difficulties holding on to the controller, and for people at higher risk of falling (e.g., older adults) due to the risk of falling when trying to stand on a raised platform. In addition, making exergames more immersive could further improve motivation and enjoyment when exercising [53, 63].

Immersive virtual reality (VR) exergaming has been shown to be more engaging than standard exercise [21]. Plante et al. [47] found that participants' heart rate and enjoyment were higher while fatigue rating was lower in VR compared to standard exercising conditions. VR also allow users to quickly identify 3D poses in space from any angle, which can be beneficial for exercising [39]. However, there are shortcomings to using VR for exercising at home, particularly because users are unable to see their real surroundings, including all of its physical objects and obstacles [39]. This creates safety concerns such as falling, tripping, and hitting objects at home. On the other hand, using augmented reality (AR) head-mounted displays (HMDs) could eliminate these safety concerns as users are able to see their real surroundings. Mostajeran et al. [39] explained how allowing users to see their real surroundings can bring three benefits, including: (1) psychological feeling of safety due to being in a familiar environment (i.e., the home); (2) physical safety from being able to view and grab onto nearby objects in case a fall is about to happen; and (3) physical safety from being able to view and avoid physical obstacles, even with any dynamic change in the environment (e.g., another person crossing the exercise area). Because AR HMDs are also wireless in nature [56] and they do not require a raised platform to support exercising, the risk of falling and tripping is further reduced. Finally, AR HMDs can help reduce accessibility issues such as difficulty holding on to video game controllers due to motor limitations [16], since users' hand gestures can be registered as inputs.

Despite the potential benefits of using AR HMDs to increase physical activity levels at home, there is limited research investigating the design of such systems to promote exercising or exergaming at home. Previous research investigating how AR HMDs can be used to promote exercising/exergaming has mostly focused on specific health-related problems (e.g., [4, 6, 14, 16, 23, 34, 39, 56]), without exploring how home objects and environments can be fully utilised to facilitate the exercise. There is a lack of foundational research investigating the wide range of exercises that can be supported through AR HMDs in home environments, and the different ways home elements may support these exercises. Therefore, to address these gaps in the literature, we identified the following research questions to explore how AR HMDs can be used to support exercising at home:

RQ1 What kind of exercises are suitable for homes in an AR environment?

RQ2 What home objects can be augmented to facilitate exercising and how can they be augmented?

In this paper, we report on an initial exploration of how homes can be augmented for exercising, to lay the foundation for future research into designing augmented home-based exergames. As part of a participatory design approach, we conducted semi-structured interviews with 17 potential users living in Australia and two senior physiotherapists. We found themes across our interviews regarding suitable home exercises, home objects, augmentation, and additional stimuli. We developed 10 recommendations for future designers and researchers of home-based exercises in AR, grouped into three categories: (1) properties of suitable home-based exercises in AR; (2) home objects that can be used for exercising at home; and (3) approaches to follow when augmenting home objects and environment to facilitate home-based exercising in AR. Our results contribute to the existing body of research on the use of AR for exercising, home applications, and everyday objects by:

- Developing 10 recommendations for designers/researchers aiming to develop home-based exercising experiences using AR HMDs;
- Presenting the first foundational study investigating the wide range of exercises that can be supported through AR HMDs in home environments, and the different ways home elements may support these exercises; and
- Laying the groundwork for future work developing home-based exergaming through AR HMDs to increase people's physical activity levels.

2 RELATED WORK

We investigated the existing body of research on the use of AR for exercising/exergaming, home applications, and everyday objects to develop an understanding of the current state-of-the-field on how AR HMDs can be designed to facilitate home-based exercising.

2.1 Augmented Reality for Exercising/Exergaming

Previous research investigating how AR can be used to promote exercising/exergaming has mainly focused on mobile AR applications, including popular location-based AR games such as Pokémon GO [7, 42, 52]. To facilitate an immersive, inclusive, and accessible exercising experience in AR, the user must be able to freely use their hands to exercise and to utilise their whole surrounding as the exercise environment. When engaging with mobile AR applications, users are not able to fully use their hands and bodies. Therefore, we need to consider AR HMDs as an alternative. Key themes appearing from previous research on exercising/exergaming through AR HMDs include individual customisation and the importance of motivational elements.

Individual customisation has been shown to affect how AR HMDs exercises should be designed. Most importantly, the target of the exercise must be tailored and adapted to the user's current physical and mental condition, to increase motivation and avoid exposing users to potential dangers if the exercise does not cater to their limitations [6, 14, 34, 56]. The user's prior expertise should also be considered when determining how much guidance they get. Jo et al. [30] found user preferences on how online yoga videos

对多个年龄组而言，它具有促进持续活动的潜力
(锻炼) 参与 [38]。运动游戏可以促进体育活动
特别是对于那些对传统锻炼缺乏动力的人群而言
[38]。然而，流行的运动游戏系统并不总是
安全或具有包容性，尤其对某些人群而言。
例如，任天堂Wii手持控制器和平衡板
对于存在运动障碍（如震颤）的人群并不适用
(例如患有帕金森病 (PD) [45]的患者)，因其难以
握持控制器；对于跌倒风险较高的人群（
如老年人），则因站立于高架平台时存在跌倒风险。
此外，增强运动游戏的沉浸式体验
可以进一步提升锻炼时的动机和愉悦感

[53, 63]。沉浸式虚拟现实 (VR) 运动游戏已被证明比标准锻炼 [21] 更
引人入胜。普兰特等人 [47] 发现，与标准锻炼条件相比，VR环境
下参与者的心率和愉悦感更高，而疲劳评分更低。VR还允许用户
从任何角度快速识别空间中的三维姿势，这对 [39] 锻炼有益。

然而，在家使用VR进行锻炼存在缺陷，
主要是因为用户无法看到真实环境，
包括其中的所有物理对象和障碍物 [39]。这会引发诸如跌倒、绊倒和撞到家中物品等安全
性问题。

另一方面，使用增强现实 (AR) 头戴式显示器 (HMDs) 可以消除这些安全性顾虑，因为用户能够看到真实周围环境。莫斯塔杰兰等人 [39] 阐释了让用户看到真实环境带来的三大益处，
包括：(1) 身处熟悉环境（即家中）带来的心理安全感；(2) 通过观察并抓握周边物体防止跌倒的人身安全；(3) 即使环境发生动态变化（如他人横穿锻炼区域），也能通过观察避开实体
障碍物的人身安全。

由于增强现实头戴显示器本身具有无线特性 [56] 且无需高架平台支撑锻炼，跌倒和绊倒风险被进一步降低。最后，增强现实头戴显示器还能缓解因运动障碍导致难以握持视频游戏控制器等可及性问题 [16]，——用户的手势可被识别为输入指令。

尽管使用增强现实头戴显示器 (AR HMDs) 提升在家锻炼时的身体活动水平具有潜在益处，但目前关于如何设计此类系统以促进家庭环境中的锻炼或运动游戏的研究仍十分有限。先前探讨AR HMDs如何促进锻炼/运动游戏的研究主要聚焦于特定健康相关问题（例如 [4, 6, 14, 16, 23, 34, 39, 56]），
却未深入探索如何充分利用家居物品和环境来辅助锻炼。当前
缺乏基础研究来系统考察增强现实头戴显示器在家庭环境中可
支持的各种锻炼形式，以及家庭元素支撑这些锻炼的不同方式。
为此，为填补文献中的这些空白，我们提出以下研究问题以探
索AR HMDs如何支持在家锻炼：

研究问题1 (RQ1) : 哪些类型的锻炼适合在家庭环境中进行 增强现实环境？

研究问题2 哪些家居物品可以被增强以促进锻炼，以及如何增强它们？

在本论文中，我们报告了对家庭环境如何运作的初步探索
可以被增强用于锻炼，为未来
研究设计基于家庭的增强型运动游戏奠定基础。作为
参与式设计方法的一部分，我们进行了半结构化
访谈，对象包括17位居住在澳大利亚的潜在用户和两位资深
物理治疗师。我们在访谈中发现了关于
适合家庭的锻炼、家居物品、增强以及附加刺激。我们为未来
增强现实中的居家锻炼设计和研究人员制定了10条建议，分为
三大类：(1) 适合居家锻炼的特性
在增强现实中；(2) 可用于在家锻炼的家居物品；
以及(3) 增强家居物品和
环境以促进增强现实中的居家锻炼时应遵循的方法。我们的结果
为现有关于使用增强现实进行锻炼的研究体系做出了贡献
锻炼、家庭应用和日常物品，具体通过：

- 为设计师/研究人员制定10条建议
旨在开发利用增强现实头戴显示器的家庭锻炼体验
增强现实头戴显示器；
- 提出首个基础研究，探讨在家庭环境中通过增强现实头戴显示器支撑的各种锻炼方式，以及家庭元素可能支撑这些锻炼的不同方式；
- 为未来工作奠定基础，开发通过增强现实头戴显示器的居家运动游戏，以提高人们的身体活动水平。

2 相关工作

我们调研了现有关于使用增强现实技术进行
锻炼/运动游戏、家庭应用及日常物品的研究成果，以
深入理解当前该领域如何通过
设计增强现实头戴显示器来促进居家锻炼。

2.1 增强现实锻炼/运动游戏中的应用

先前关于如何利用增强现实促进锻炼/运动游戏的研究主要集中于移动增强现实应用，包括《精灵宝可梦GO》 [7, 42, 52] 等流行的基于位置的AR游戏。为了在增强现实中实现沉浸式、包容性且易于使用的锻炼体验，用户必须能够自由运用双手进行锻炼，并将整个周边环境作为锻炼环境。当使用移动增强现实应用时，

用户无法充分运用他们的手和身体。因此，
我们需要考虑将增强现实头戴显示器作为替代方案。过往关于
通过增强现实头戴显示器进行锻炼/运动游戏的研究中出现的关键主题包括个性化定制和激励元素的重要性。

研究表明，个性化定制会影响增强现实头戴显示器中锻炼活动的设计。最重要的是，锻炼目标必须根据用户当前身心状态进行定制调整，以增强动机，并避免因锻炼内容不符合用户身体限制而使其面临潜在危险 [6, 14, 34, 56]。在确定给予用户多少指导时，还应考虑其用户先前经验。

Jo等人 [30] 发现用户对在线瑜伽视频呈现方式的偏好

can be presented dynamically through AR HMDs, depending on the user's prior expertise in yoga, with experienced users preferring user-anchored layout (a screen that follows the user's head) and less experienced users preferring trainer-anchored layout (a screen that moves following the trainer's viewpoint). Concerning the types of virtual elements to be added in AR, the game environment should be tailored based on user type and player type (e.g., [8]) [56]. Individuals with low intrinsic motivation were found to prefer an immersive, illusory environment (e.g., beautiful landscapes), whereas those with high intrinsic motivation preferred the real environment with the addition of vital data (e.g., heart rate, blood pressure, and exercise time) or feedback regarding the exercise [56]. Sports environment was also found to be associated with high intrinsic motivation, but not low intrinsic motivation [56]. The game narrative, which is an important motivational element, should also be tailored to the individual (e.g., not involving war scenarios for older adults as many of them experienced World War II) [56].

Motivational elements, including social elements, storytelling, and rewards, are important considerations for designing an engaging experience. Social elements have been regarded as an important part to enhancing motivation to exercise among older adults [39, 56]. Stamm et al. [56] reported that their older adults participants greatly valued social interaction and wished for a multiplayer mode, even if they preferred a comparison with their own previous data to show progress instead of a comparison with other people. Storytelling has also been perceived as an important motivator for exercising [56], while rewards should be used to increase people's desire to complete the exercises [14].

Previous research investigating the use of AR HMDs to support exercising/exergaming has focused on healthcare contexts, such as rehabilitation for shoulder injuries [23], stroke [4, 6, 14], and cognitive/motor conditions [16] or physical training for older adults [34, 39, 56]. Studies investigating the use of AR HMDs for physical training for older adults have particularly focused on employing virtual coaches [34, 39, 56]. Virtual coaches can provide supervision and real-time feedback in the absence of a physiotherapist [34], and are also socially accepted by older adults [39]. Overall, it has been shown that the use of AR HMDs for home exercises could increase people's adherence to exercising, although people needing rehabilitation and older adults have different requirements from other user groups due to additional risks and factors.

Studies investigating the use of AR HMDs for rehabilitation have also discussed the benefits of using haptic feedback and tangible objects in facilitating exercises [4, 23]. The incorporation of haptic technology or tangible objects for virtual environments can provide physical means to interacting with virtual objects, a more natural interaction mode, and a chance to improve the user's motor strengths [4, 14, 23]. Garcia Hernandez et al. [23] also argued that only interacting with virtual midair objects during shoulder rehabilitation could diminish or reduce the limbs' proprioception since the user's hands are not in contact with an object. However, haptic devices can be expensive, bulky, heavy, and difficult to put on [4, 6]. Wearing haptic gloves may also restrict freedom of movement [6] and interfere with assessment of natural hand movements [14]. On the other hand, using real tangible objects can provide the same benefits, while also decreasing the hardware and software complexities of haptic systems [4]. Tangible objects, such as mugs

[4] and dowel rod [23], have been used in conjunction with AR HMDs to facilitate rehabilitation. However, there is a lack of studies investigating how other tangible objects can be used to support exercising through AR HMDs.

2.2 Augmented Reality for Home Applications and Everyday Objects

As AR technologies continue to develop and become more accessible, researchers have begun investigating how AR can be used to improve the experience of living at home. Several studies have investigated how AR can be used as a tool for supporting assistive home modifications [5, 9, 25]. Bonanni et al. [10] designed and built a conventional kitchen augmented with projection of digital information onto objects and surfaces, to support users when working in the kitchen. Ventä-Olkkinen et al. [61] investigated how home windows can be augmented to present additional information to users by augmenting windows, while Colley et al. [15] explored how AR can be used to help remember things at home, such as remembering the Wi-Fi password or the history behind a home object. Knierim et al. [32] conducted an initial exploration on how AR can seamlessly be integrated into people's home environment to benefit users at home, identifying potential use-cases and opportunities. While exercise was not the main focus of their research, some participants from this study discussed topics relating to physical activity. For example, the study reported that one participant imagined a virtual trainer who can provide necessary exercise instructions, correct mistakes, and prevent injuries. Participants also imagined how existing devices or artefacts at home can be augmented (device augmentation), such as augmenting a weighing scale to show a more detailed breakdown of a person's weight and how it compares to four weeks ago, or augmenting a couch to show how much time a person has spent idle in front of the television and not being active. Among studies investigating the use of AR for home applications, multiple authors have stressed the importance of selective augmentation, to prevent information and cognitive overload [32], since attention is limited [10]. The quality and quantity of augmentation needs to be carefully considered based on the amount and type of attention for each task.

Using everyday tangible objects for home AR applications can bring similar benefits to using tangible objects for exercising, by providing physical means to interacting with virtual objects and a more natural interaction mode [4, 14, 23]. However, for many previous studies on the use of AR for home applications, virtual images were mainly overlaid on flat surfaces (e.g., a virtual grab bar on the wall [9] or a virtual interface displaying information on a window glass [61]), or simply floating in the 3D space near an object (e.g., a rectangular window displaying the Wi-Fi password above a Wi-Fi router [15]). Holding virtual objects with the lack of tactile stimuli was deemed unsatisfying for some people [33]. To prevent a brittle experience in the virtual environment, the immersive capabilities of audio and visual outputs need to be matched with equally immersive haptic experiences [27]. The theme of device augmentation from [32] also highlighted people's desire to use AR to add new functionalities to existing home objects that were considered well-integrated into the home environment, which aligns with the idea that existing, well-integrated home objects can

可通过增强现实头戴显示器动态呈现，这取决于用户先前在瑜伽方面的经验。经验丰富的用户倾向于用户锚定布局（屏幕跟随用户头部移动），而经验较少的用户则偏好教练锚定布局（屏幕跟随教练视角移动）。关于增强现实中应添加的虚拟元素类型，游戏环境应根据用户类型和玩家类型进行定制（例如[8]）[56]。研究发现，内在动机较低的个人更偏爱沉浸式虚幻环境（如美丽景观）。

而那些具有高内在动机的人则更喜欢真实环境，并附加生命体征数据（如心率、血压和锻炼时间）或关于锻炼的反馈[56]。

运动环境也被发现与高内在动机相关，但与低内在动机无关[56]。游戏叙事作为一种重要的激励元素，也应因人而异（例如，避免为老年人设计涉及战争场景的内容，因为他们中许多人经历过第二次世界大战）[56]。

激励元素，包括社交元素、故事叙述以及奖励，是设计引人入胜体验的重要考量因素。社交元素一直被视为增强老年人锻炼动机的重要组成部分[39, 56]。

Stamm等人[56]报告称，他们的老年参与者非常重视社交互动，并希望有多人模式，尽管他们更倾向于与自己的先前数据进行比较以显示进展，而非与他人比较。故事叙述也被认为是激励锻炼[56]的重要因素，而奖励则应被用来增强人们完成锻炼[14]的意愿。

先前关于使用增强现实头戴显示器以支撑锻炼/运动游戏的研究主要集中在医疗保健背景，例如肩部损伤[23]，中风[4, 6, 14]，康复或认知/运动障碍[16]的康复，以及老年人的体能训练[34, 39, 56]。研究探讨了使用增强现实头戴显示器进行体能针对老年人的训练特别注重采用虚拟教练[34, 39, 56]。虚拟教练能够在缺乏物理治疗师的情况下提供监督和实时反馈[34]，并且也被老年人社会接受[39]。总体而言，研究表明使用增强现实头戴显示器进行家庭锻炼可以提高人们对锻炼的坚持度，尽管需要帮助的人们康复和老年人有着不同于其他用户群体的需求，因为存在额外的风险和因素。

研究增强现实头戴显示器在康复中的应用也探讨了使用触觉反馈和有形物体辅助锻炼的益处[4, 23]。在虚拟环境中整合触觉技术或有形物体，可以提供与虚拟物体互动的物理手段、更自然的交互模式，以及提升用户运动力量的机会[4, 14, 23]。加西亚·埃尔南德斯等人[23]还指出，在肩部康复过程中仅与虚拟空中物体互动可能会削弱或减少肢体的本体感觉，因为用户的手并未接触实际物体。然而，

触觉设备可能价格昂贵、笨重且难以穿戴[4, 6]。佩戴触觉手套还可能限制运动自由度[6]，并干扰对自然手部运动的评估[14]。另一方面，使用真实有形物体可以提供相同的益处，同时降低触觉系统的硬件和软件复杂性[4]。有形物体，如杯子

[4]和圆棒[23]，已与增强现实结合使用头戴式显示器有助于康复。然而，目前缺乏研究探讨如何利用其他有形物体来支撑通过增强现实头戴显示器进行锻炼。

2.2 增强现实家庭应用与日常物品中的应用

随着增强现实技术的持续发展和日益普及，研究人员开始探索如何利用AR技术提升居家生活体验。多项研究已探讨了如何将增强现实作为辅助性家庭改造工具[5, 9, 25]。Bonanni等人[10]设计并构建了一个通过将数字信息投射到物品和表面来增强的传统厨房，以支持用户在厨房中的操作。文塔-奥尔科宁等人[61]研究了如何通过增强窗户来向用户展示额外信息，而科利等人[15]则探索了如何利用AR帮助记忆家庭事务，例如记住Wi-Fi密码或家庭物品背后的历史。Knierim等人[32]对AR如何无缝融入人们的家庭环境以惠及用户进行了初步探索，识别了潜在用例和机遇。虽然锻炼并非他们研究的主要焦点，

这项研究中的一些参与者讨论了与体育活动相关的话题。例如，研究报告称，一位参与者设想了一位虚拟教练，能够提供必要的锻炼指导、纠正错误并预防受伤。参与者还设想了如何对家中现有设备或物品进行增强（设备增强），比如增强体重秤以显示一个人体重的更详细分解及其与四周前的对比，或者增强沙发以显示一个人在电视机前久坐不动的时长。在调查增强现实用于家庭应用的研究中，多位作者强调了选择性增强的重要性，以防止信息和认知超载[32]，因为注意力是有限的[10]。需要根据每项任务的注意力数量和类型，仔细考虑增强的质量和数量。

将日常有形物体用于家庭增强现实应用可以通过利用有形物体进行锻炼，带来类似的益处。提供与虚拟物体交互的物理手段和一种更自然的交互模式[4, 14, 23]。然而，对于许多先前关于在家庭应用中使用增强现实的研究，虚拟图像主要叠加在平坦表面上（例如，墙上的虚拟抓杆[9]或显示信息的虚拟界面窗口[61]），或简单地漂浮在附近的3D空间中物体（例如显示Wi-Fi密码的矩形窗口

位于Wi-Fi路由器[15]上方）。对于某些人来说，缺乏触觉刺激的虚拟物体抓握体验被认为不尽如人意[33]。为了避免虚拟环境中的脆弱体验，音频和视频输出的沉浸式能力需要与同等沉浸的触觉体验相匹配[27]。来自[32]的设备增强主题也突显了人们希望使用增强现实为现有家居物品增添新功能的愿望。被认为很好地融入了家庭环境，这与现有、高度融合的家居物品可以作为

be used as tangible objects that can be augmented to support home exercising.

Previous studies investigating how everyday tangible objects can be utilised to enhance experiences in AR have mainly investigated how they can be used as mixed/augmented reality inputs, either by overlaying the entire tangible object with a virtual object [64], or only overlaying the edges of the tangible object (e.g., the rim of a cup) [26]. Overlaying the entire tangible object with a virtual object can be challenging, as it is difficult to find everyday objects that perfectly match the digital function geometrically and semantically [26]. Hettiarachchi and Wigdor [27] investigated how haptic experiences can be introduced for virtual objects by matching them with a similarly-shaped everyday object. For example, a virtual torch can be matched with a soda can, while a virtual light saber can be matched with a wine bottle. The authors argued that it is important to select a physical object that is as similar as possible to the virtual object in terms of shape and size for the user's suspension of disbelief. On the other hand, a mismatch would negatively affect the user's feeling of immersion and engagement [54]. In the case of the virtual light saber example, a wine bottle can be a good match if the intention is only for the user to hold the handle of the light saber. However, if the user needs to be able to feel being hit by the light sabre, the wine bottle might not be a good match and a different, longer physical object needs to be chosen instead. This highlighted the importance of carefully considering the specific use-cases before deciding what physical objects can be augmented to facilitate home exercising/exergaming, and the shape and size of the object in relation to the intended use-case.

2.3 Conclusions

Previous studies on the use of AR (both mobile and HMDs) for exercising or exergaming have highlighted the importance of individual customisation, elements to consider to increase motivation and immersion, and using real tangible objects to enhance the exercising experience. Previous research investigating how AR HMDs can be used to promote exercising/exergaming has mostly focused on specific health-related domains, such as rehabilitation or home training for older adults. There is a lack of foundational research investigating the wide range of exercises that can be supported through AR HMDs in home environments. This gap gives rise to **RQ1: What kind of exercises are suitable for homes in an AR environment?** Meanwhile, previous studies on AR for home applications and everyday objects have provided two important insights to consider for the design of home-based exercising/exergaming experiences through AR HMDs. First, the quality and quantity of augmentation for homes must be carefully considered depending on each task. Second, everyday tangible objects at home can be used to enhance the experience of exercising at home, but the intended use-cases must be considered before selecting the home objects that can be augmented. Despite these insights, there is still limited knowledge on the types of home objects that can be augmented for different home exercise-related use-cases. As a result, we identified **RQ2: What home objects can be augmented to facilitate exercising and how can they be augmented?** Therefore, our research aims to build on previous research by investigating the wide range of exercises that can be supported through AR HMDs in

home environments (through **RQ1**), and the different ways home elements may support these exercises (through **RQ2**).

3 METHOD

To address our research questions RQ1 and RQ2, we employed participatory design to gain insights from future users as to how they might want to exercise in an AR environment in their own home. Simonsen and Robertson [55] demonstrated that participatory design can be employed: (a) to design digital parts or layers in an originally non-digital environment to create a new digitally enhanced experience; and (b) for studies involving mixed reality environments. As our research investigates how homes (an originally non-digital environment) can be augmented (with digital layers) to facilitate an enhanced exercising experience in AR, participatory design is an appropriate approach following the examples set out by Simonsen and Robertson [55].

For our initial exploration, we conducted semi-structured interviews with 17 potential users to understand how people exercise, or would like to exercise at home, and how that could be supported in an AR environment. To supplement results from our pool of potential users, we conducted semi-structured interviews with two senior physiotherapists to gain further, professional insights on how exercising can be done at home particularly in an AR environment. The senior physiotherapists' experience and expertise can help bridge any knowledge gap from interviews with our current pool of potential users. Qualitative data from semi-structured interviews was analysed with a six-phase thematic analysis process as outlined by Braun and Clarke [11]: familiarising the data, generating initial codes, searching for themes (in this case, themes about qualities that make safe and suitable home exercises in AR, home objects that can be used for home exercises in AR, and how home objects and environments can be augmented to support exercising), reviewing the themes, defining and naming the themes, and producing the report. Data was analysed and coded manually by the first author with an inductive approach. Our research received approval from the university's human research ethics committee and an informed consent was obtained from all participants.

3.1 Interviews with Potential Users

We recruited participants living in any type of housing in Australia, who were 18 years or older. Interviews were conducted online for a maximum of 20 minutes per participant. Participants were offered a \$5 voucher for their participation. During the interview, participants were asked to describe their level of physical activity. Participants who reported having done any exercise at all were asked to share some details on their exercising habit, including: (1) how often they exercise; (2) what kind of exercise they do; (3) where they do the exercise; and (4) how they exercise during the COVID-19 lockdown. Meanwhile, participants who reported not doing any exercise were asked if there was any particular reason for their lower levels of physical activity and to describe their level of interest in trying out different types of exercises. Then, all participants were asked if they have exercised or considered exercising at home before, followed by questions about the types of exercise they think can be done at home and how they can be done in terms of tools, equipment, or technology needed. Towards

可被增强以支撑家庭的有形物体使用的理念一致锻炼。

先前研究探讨日常有形物体如何

被用于增强增强现实体验时，主要聚焦于它们如何作为混合/增强现实输入被使用。具体方式包括将整个有形物体完全覆盖以虚拟物体[64]，或仅覆盖有形物体的边缘（例如，杯子的边缘）[26]。将整个有形物体完全覆盖以虚拟物体可能具有挑战性，因为很难找到几何和语义上

与数字功能完美匹配的日常物品。赫蒂阿拉奇和维格多[27]研究了如何通过将虚拟物体与

形状相似的日常物品。例如，虚拟火炬可以与苏打罐匹配，而虚拟光剑则可与酒瓶匹配。作者们强调，选择形状和大小尽可能接近

虚拟物体的物理物体，对用户的怀疑暂停至关重要。反之，不匹配会负面影响

用户的沉浸感和参与度[54]。在以虚拟光剑为例，酒瓶可以成为一个不错的匹配对象。如果意图仅是让用户握住光剑的手柄，那么酒瓶尚可胜任。但若用户需要感受被光剑击中的触感，酒瓶可能就不太适合，而应选择另一种更长些的物理物体。这突显了仔细考量具体需求的重要性

在决定哪些物理对象可以被增强之前考虑用例以促进家庭锻炼/运动游戏，以及对象的形状和大小与预期用例之间的关系。

2.3 结论

先前关于使用增强现实（包括移动设备和头戴式显示器）进行锻炼或运动游戏的研究强调了个人定制的重要性、提升动机和沉浸感的考量因素，以及利用真实有形物体来增强锻炼体验。以往研究探讨如何通过增强现实头戴显示器促进锻炼/运动游戏时，主要集中于特定健康相关领域，如老年人康复或家庭训练。目前缺乏基础研究来探索在家庭环境中通过增强现实头戴显示器可支持的各种锻炼方式。这一空白引出了研究问题1：在增强现实环境中，哪些类型的锻炼适合家庭环境？同时，先前关于增强现实家庭应用和日常物品中的研究为设计基于增强现实头戴显示器的居家锻炼/运动游戏体验提供了两个重要洞察。首先，必须根据每项任务仔细考量对家庭环境增强的质量和数量。其次，家中的日常有形物体可用于提升在家锻炼的体验，但在选择可增强的家居物品前必须考虑预期用例。尽管存在这些洞察，对于不同家庭锻炼相关用例中可增强的家居物品类型仍知之甚少。因此，我们提出了研究问题2：哪些家居物品可被增强以促进锻炼，以及如何增强它们？故而，我们的研究旨在通过调查家庭环境中通过增强现实头戴显示器可支持的各种锻炼方式（通过研究问题1），以及家居物品的不同增强方式，来拓展先前研究。

家庭环境（通过研究问题1），以及家居物品的不同增强方式元素可能支撑这些锻炼（通过研究问题2）。

3 方法

为解答我们的研究问题研究问题1和研究问题2，我们采用了参与式设计方法，从未用户处获取关于他们可能希望如何在自家增强现实环境中进行锻炼的洞察。西蒙森和罗伯逊[55]证明参与式设计可用于：(a) 设计数字部分或层次，

在原本非数字环境中创建新的数字化增强体验；以及(b) 涉及混合现实环境的研究。由于我们的研究探讨家庭环境（原本

非数字环境）可通过（数字层）增强以促进增强现实中的强化锻炼体验，参与式设计是遵循既定范例的合适方法如西蒙森和罗伯逊[55]所示。

在初步探索阶段，我们与17位潜在用户进行了半结构化访谈，以了解人们如何锻炼，或

希望在家锻炼，以及如何为此提供支撑。

一个增强现实环境。为了补充我们潜在用户群体的结果，我们对两位资深物理治疗师进行了半结构化访谈，以获取关于如何在家中进行锻炼的专业见解，特别是在增强现实环境中。

资深物理治疗师的经验和专业知识有助于弥合在当前潜在用户群体访谈中可能存在的知识差距。半结构化访谈的定性数据按照布劳恩和克拉克提出的六阶段主题分析流程进行分析：

熟悉数据，生成初始[11]

代码，寻找主题（在本例中，是关于特质的主题）。这些特质使增强现实中的家庭锻炼安全合适，以及家居物品如何被用于增强现实中的家庭锻炼，以及家居物品和环境如何被增强以支撑锻炼），回顾这些主题，定义并命名主题，并生成报告。数据由第一作者手动分析和编码采用归纳法。我们的研究获得了

大学人类研究伦理委员会的批准，并取得了所有参与者知情同意。

3.1 潜在用户访谈

我们招募了居住在澳大利亚各类住宅中的参与者，年龄需18岁或以上。访谈通过在线方式进行，每位参与者最多20分钟。参与者将获得5美元代金券作为报酬。在访谈过程中，参与者被要求描述他们的体育活动等级。报告曾进行过任何锻炼的参与者被要求分享一些关于他们锻炼习惯的细节，包括：

(1) 锻炼频率；(2) 锻炼类型；(3) 锻炼地点；以及(4) 他们在新冠封锁期间如何进行锻炼。与此同时，报告未进行任何锻炼的参与者被询问是否有任何特定原因导致他们的体育活动等级较低，并描述他们对尝试不同锻炼种类的兴趣水平。然后，

所有参与者都被询问是否曾经在家锻炼或考虑过在家锻炼，随后是关于他们认为可以在家进行的锻炼类型以及如何通过所需工具、设备或技术实现的提问。接近

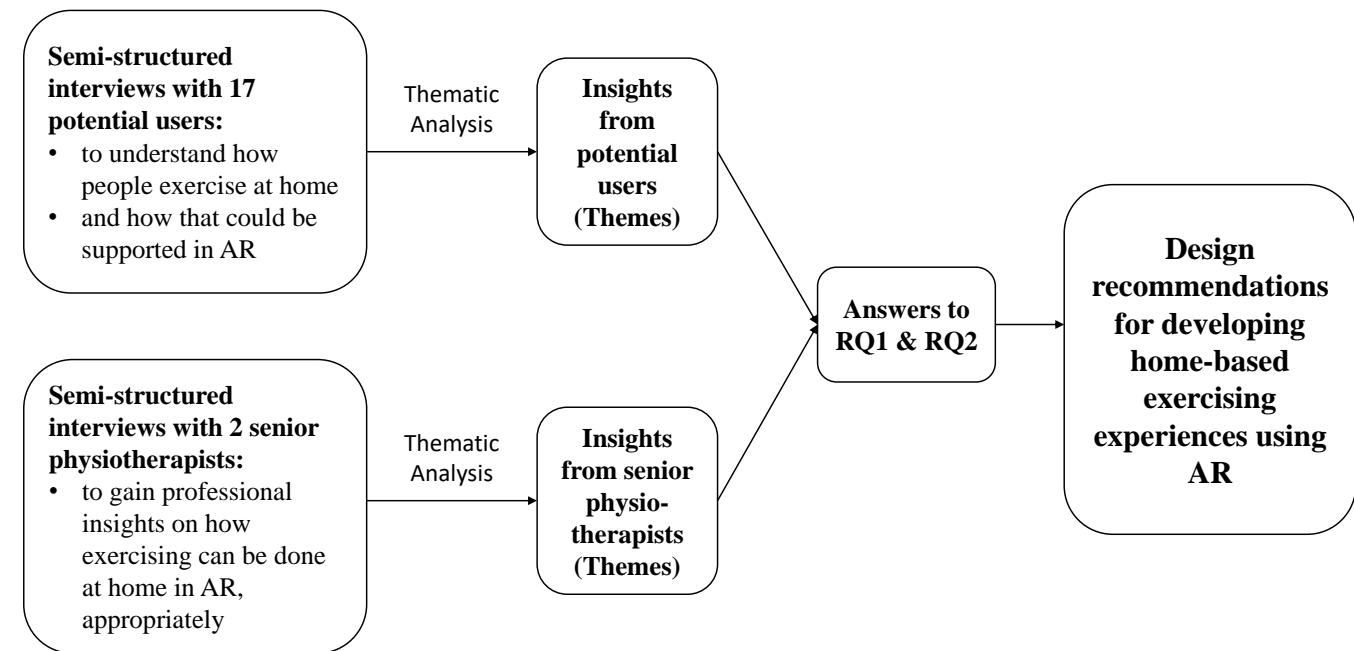


Figure 1: Participatory design approach for this research

the end of the interview, participants were reminded of the context of the research, and then asked how they feel the exercises they have discussed can be replicated in an AR environment, especially if they do not have the necessary tools or equipment to exercise, such as a dumbbell. Participant demographic included 11 female and 6 male, with ten aged 25-34, three 18-24, two 35-44, and one each of 45-54 and 55-64.

3.2 Interviews with Physiotherapists

Interviews were conducted online for a maximum of 30 minutes per participant. Participants were not offered monetary compensation; instead they were invited for continuous collaboration as the research progresses. Participants were asked to share their responsibilities/activities at work, exercises that their clients can benefit from, exercises that can be done at home, and how these exercises can be done at home in terms of tools, equipment, or technology needed. Participant demographic included 1 female and 1 male from two different clinics, both aged 55-64, who both work professionally as senior physiotherapists.

4 INSIGHTS FROM POTENTIAL USERS

We identified seven themes grouped into two categories, relating to: (1) suitable home-based exercises; and (2) home objects, augmenting homes for exercising, and motivational elements beyond augmentation. In this section, we present each theme with supporting participant quotes.

4.1 Category 1: Suitable Home-based Exercises

Our first three themes related to defining suitable home-based exercises. The themes defined that home-based exercises should

1) be mostly stationary, 2) use minimal special equipment, and 3) incorporate both structure and novelty.

Theme 1: Home-based exercises should mostly be stationary. Not all exercises can be done inside the house; for safety reasons and for preservation of the home, home-based exercises should not involve large, aggressive movements. A 'home' can look different for different people (e.g., a studio apartment in a student accommodation versus a large house with a backyard, a dedicated home exercise space versus multi-purpose areas). However, we found a common theme in terms of the types of exercises that participants reported doing inside the house: they were mainly stationary. Participants described stationary exercises as not needing to move around the room too much and usually taking place in a set position. This included exercises such as strength-based exercises (lifting weights or core exercises such as push-ups), flexibility exercises (touching hands behind the back and other workouts during yoga), martial arts (Tai Chi), or light aerobic activities (jumping, burpees, dancing). Stationary exercising is largely to avoid "stuff getting broken" (P03) inside the house, especially if people become too immersed in the exercise activity.

Theme 2: Home-based exercises should use minimal special equipment. To avoid cluttering the home environment and to minimise the financial barriers to exercising, home-based exercises should require little to no specialised equipment. Some participants shared that part of the reason they do not exercise at home is "because of the lack of equipment" (P01). Participants reported that exercise tools and equipment can be costly and take up storage space (particularly in smaller homes). Therefore, some participants preferred home exercises that require little to no equipment (e.g., only using their body or requiring a yoga mat). One participant shared how they had to be creative when it comes to exercising at

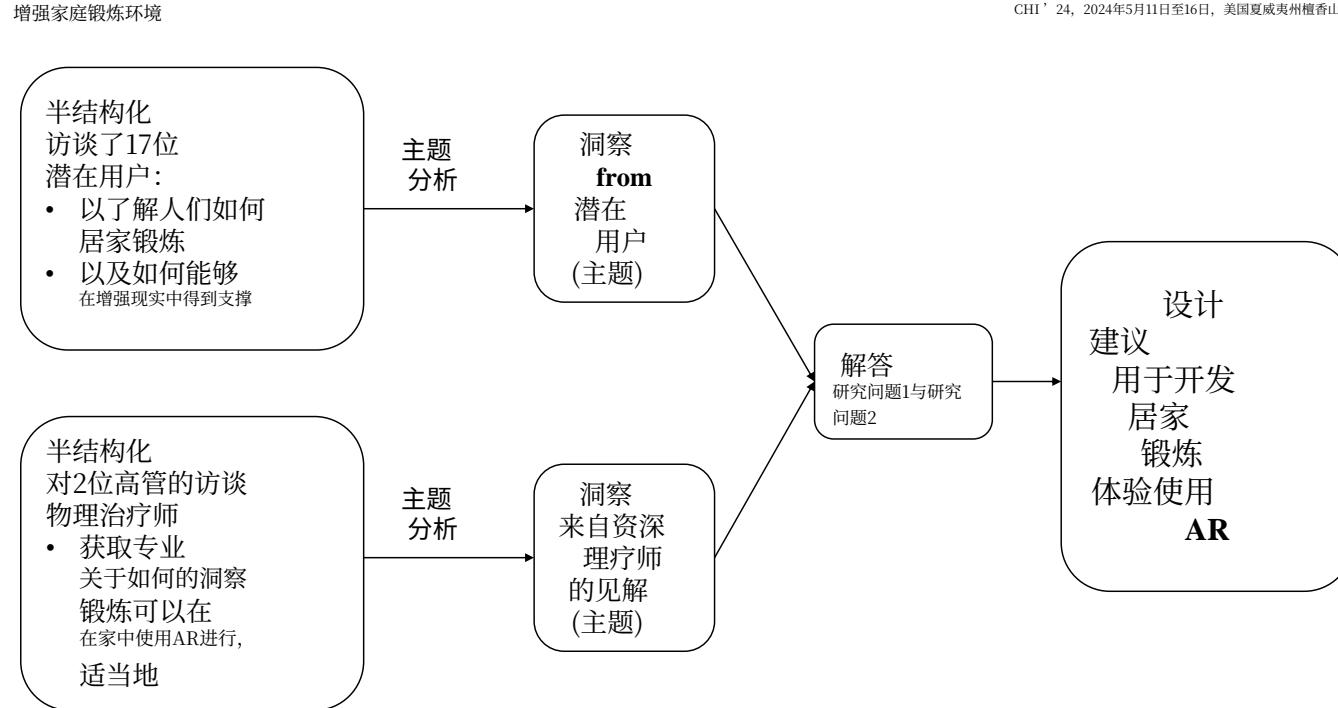


图1：本研究的参与式设计方法

访谈结束时，参与者被提醒了上下文
研究中，然后询问他们对自己讨论过的锻炼方式
如何在增强现实环境中复现的感受，特别是
当他们缺乏必要的工具或设备进行锻炼时。
例如哑铃。参与者人口统计包括11名女性
和6名男性，其中10人年龄25-34岁，3人18-24岁，2人35-44岁，以及1人
分别处于45-54岁和55-64岁年龄段。

3.2 物理治疗师访谈

访谈通过在线方式进行，每位参与者最多30分钟。参与者未获得金钱补偿；而是被邀请随着研究进展持续合作。参与者被要求分享其工作职责/活动、其客户可受益的锻炼项目、可在家进行的锻炼项目，以及这些锻炼在家进行时所需的工具、设备或技术。参与者人口统计包括来自两家不同诊所的1名女性和1名男性，年龄均为55-64岁，均为资深物理治疗师。

4 潜在用户的见解

我们识别出七个主题，归为两类，涉及：(1)适合的家庭锻炼；(2)家居物品，用于增强家庭环境以进行锻炼，以及超越增强的激励元素。本节中，我们将通过参与者引述逐一呈现每个主题。

4.1 类别1：适合的家庭锻炼

我们的前三个主题与定义适合的家庭锻炼相关。这些主题定义了居家锻炼应

1) 主要为静态的，2) 使用最少特殊设备，以及3) 结合结构和新颖性。

主题1：居家锻炼应主要为静态的。并非所有锻炼都适合在室内进行；出于安全性和保护家庭环境的考虑，居家锻炼不应包含大幅度的剧烈动作。不同人的“家”可能形态各异（例如学生宿舍中的单间公寓对比带后院的大房子，专用家庭锻炼空间对比多功能区域）。但我们发现参与者报告的室内锻炼种类存在一个共同主题：它们主要是静态的。参与者将静态锻炼描述为无需在房间内过多移动，通常固定在一个位置完成。这包括力量训练（举重或如俯卧撑等核心训练）、柔韧性锻炼（瑜伽中的双手背后相触等动作）、武术（太极）或轻度有氧运动（跳跃，

波比跳、跳舞）。静态锻炼主要是为了避免房屋内“物品被损坏”（P03），尤其是当人们过于沉浸在锻炼活动中时。

主题2：居家锻炼应使用最少的专业设备。为避免家庭环境杂乱并降低锻炼的经济障碍，居家锻炼应几乎或完全不需要专业设备。部分参与者表示，他们不在家锻炼的部分原因是

“因为缺乏设备”（P01）。参与者报告称，锻炼工具和设备可能价格昂贵且占用存储空间（尤其是在小户型住宅中）。因此，一些参与者更倾向于选择几乎或完全不需要设备的家庭锻炼（例如，

仅使用他们的身体或需要一张瑜伽垫）。一位参与者分享了他们在如何在家锻炼时必须发挥创造力，

home because “the limiting factor with exercising at home is you don't have all access to all the equipment you need” (P13), particularly when exercising at home during COVID-19 lockdowns: *P13: I had to come up with creative ways to essentially replicate what I do in the gym without the heavyweights. So, what I did there was kind of try to find body weight alternative exercises; instead of a bench press I did a push up, so a lot of that replaced with body weight exercises*”.

Theme 3: Home-based exercises should incorporate both structure and novelty. Home-based exercises can be more effective when there is an evolving structure that people can follow. Some participants preferred shorter, targeted exercises that they can do on a regular basis. Examples include watching or listening to video or audio instructions, such as fitness videos from YouTube. Participants indicated that these video or audio instructions provide a structured and effective 10-30 minute workout that they could fit into their daily routine. One participant noted that following these instructions “is more convenient and more easy to continue” (P06). Having instructions to follow can be beneficial for people to exercise ‘correctly’ at home: *P14: “You can do yoga and Pilates [at home], but the thing with these exercises is that you need to know what you're doing, otherwise it is pointless”*. On the other hand, having a structure that is too rigid and repetitive can backfire and demotivate some participants from continuing the exercise routine: *P08: “I resorted to online YouTube videos as I didn't have access to gym equipment at that time, but I did find that it got quite repetitive and I did lack a bit of motivation during then”*. Comments related to this theme indicated that both structure and novelty needs to be incorporated to facilitate effective home exercises.

4.2 Category 2: Home Objects, Augmentation, and Beyond Augmentation

Our final themes from the semi-structured interviews with potential users related to home objects, augmentation, and considerations beyond augmentation. The themes related to 4) suitable home objects for exercising at home, 5) individual preferences for home object augmentation, 6) augmenting the home environment, and 7) motivational elements.

Theme 4: Different home objects can be used for different exercises. Participants shared a variety of home objects that they have used as replacements for exercise tools or equipment. Most participants had some ideas when it comes to a replacement for weightlifting. Common objects mentioned by participants were water bottle, cans, kettle, milk bottle, iron, or other kitchen utensils for lifting, instead of using a dumbbell. Objects with a handle were also preferred as the handle made it easier for them to lift. Some participants added that they like how using objects like a water bottle means the weight can be adjusted for a more personalised weightlifting exercise, using water or even sand. If these objects are not heavy enough, some participants shared that they could resort to using university textbooks, laptops, backpacks, rice bags, shopping bags filled with items, or even a bin. Interestingly, a couple of participants mentioned lifting their pets (P17) or “children” (P11) as a form of exercising. However, some participants expressed their concerns that household items might not be functionally suitable for exercising or could even lead to injuries. For example, one participant (P05) shared that having a home-based object that has

the same weight as a dumbbell does not necessarily mean it has the right handle that can support a safe and correctly-executed weightlifting exercise to avoid injuries. Meanwhile, another participant (P03) shared how difficult it is to find two items that would weigh the exact amount in your household, to act as two dumbbells that you would need to lift at the same time for time efficiency and balance.

While participants had many suggestions about home objects for weightlifting, participants found it more difficult to think of replacements for other types of exercises. Some participants discussed using a piece of clothing if they do not have resistance bands or elastic bands: *P11: “I guess you might be able to use clothing, like recycle some clothing that you don't care about, like old stockings”*. Similarly, another participant (P20) added that the elastic waist band in pants could be tied to a door, stretched, and then used for specific exercises. A participant (P12) shared how they used a towel as a visual line to exercise their legs when lying on their back, such that their legs could continuously move above and below the towel. Another participant (P13) recounted how they tried tying up a bed sheet and hanging it over an open door to do pull-ups, although the participant added that this exercise was one of the hardest exercises to try to replicate.

Another common suggestion for non-weightlifting exercises was to use furniture at home. Some participants discussed having utilised furniture as a form of support to help them exercise. For example, a participant (P11) shared that chairs and the wall can be used for “stretching out the nerves or as props for doing squats as a stability thing so you don't fall over”. Participants added that a few things at home can be used for stepping or jumping exercises, such as the edge of the bed (or a mattress if it is on the floor) or other surfaces like tables and chairs. Similarly, fixtures can be used as a form of support to exercise, like “the edge of a bath” for “squats” or “the edge of the kitchen table to do push-ups” (P07).

Theme 5: Preference for home object augmentation for exercising varies between individuals. We found two types of preferences for augmentation of home objects for exercising in an AR environment – augmenting objects to resemble exercise equipment and to resemble other personally motivating objects. For object augmentation to resemble exercise equipment, participants shared ideas like augmenting a table into a gym platform or a water bottle into a dumbbell. One participant (P19) shared how having the option to make a water bottle look like a dumbbell would make them “feel more professional and motivate [them] to exercise even more”. Another participant (P21) noted that exercising using a bottle does not really feel like an exercise and therefore preferred for the water bottle to be augmented. For object augmentation to resemble personally motivating objects, preferences included augmenting a water bottle or a rice bag into an animal, or something else that might be unusual, “completely different from what it should be, depending on the personality of the person”, like “a very large red lipstick” (P19). One participant suggested that the edge of a bath and a kitchen table could be augmented into “a cute chair” and “a very huge stone”, respectively (P07). Another suggested that a rice bag could be augmented into a pet dog that needs to be carried and rescued (P08). However, some participants did not like the idea of having ‘personally motivating’ augmented objects when exercising: *P20: “First of all, if it's a dog then.. I need to worry about whether it's*

因为“在家锻炼的限制因素是你无法获得所有你需要的设备”（参与者13），尤其是在新冠肺炎封锁期间在家锻炼时：参与者13：“我必须想出创造性的方法，基本上复制我在健身房所做的，但没有那些重量。所以，我所做的是尝试找到替代性自重训练；用俯卧撑代替卧推，因此很多都是用自重锻炼来替代的”。

主题3：居家锻炼应兼顾结构和新颖性。当人们能遵循一个不断演进的锻炼框架时，居家锻炼会更有效。

部分参与者更偏好短时、有针对性的定期锻炼方式，例如观看或收听视频或音频指导，如YouTube上的健身视频。

参与者表示，这些视频或音频指导提供了10-30分钟结构化且高效的锻炼方案，能轻松融入日常生活。一位参与者指出，遵循这些指导“更方便且更容易坚持”

(P06)。遵循指导有助于确保居家锻炼动作的准确性：P14：“你[在家]，可以做瑜伽和普拉提，但关键在于必须掌握正确方法，否则毫无意义”。另一方面，过于刻板重复的框架可能适得其反，导致部分参与者放弃锻炼计划：

P08: “我当时没有健身器材可用，所以只能求助于在线YouTube视频，但我发现内容相当重复，那时也缺乏一些动力。”与该主题相关的评论指出，需要结合结构和新颖性来促进有效的家庭锻炼。

4.2 类别2：家居物品、增强以及超越增强

我们通过对潜在用户的半结构化访谈得出的最终主题涉及家居物品、增强以及超越增强的考量。这些主题包括：4)适合在家锻炼的家居物品，5)个人对家居物品增强的偏好，6)增强家庭环境，以及7)激励元素。

主题4：不同的家居物品可用于不同的锻炼。参与者分享了多种他们曾用作锻炼工具或设备替代品的家居物品。大多数参与者对举重训练的替代品有一些想法。参与者常提到的物品包括水瓶、罐头、水壶、牛奶瓶、熨斗或其他厨房用具，用于替代哑铃进行举重。带有把手的物品也更受青睐，因为把手使举重更容易。一些参与者补充说，他们喜欢使用水瓶这样的物品，因为可以通过加水或沙子来调整重量，实现更个性化的举重训练。如果这些物品不够重，一些参与者表示他们会转而使用大学教材、笔记本电脑、背包、米袋等。

装满物品的购物袋，甚至是一个垃圾桶。有趣的是，有几位参与者提到会举起他们的宠物 (P17) 或“孩子”

(P11) 作为一种锻炼形式。然而，部分参与者表达了他们的担忧，认为家居用品可能功能上不适合锻炼，甚至可能导致受伤。例如，一位参与者 (P05) 提到，拥有一个与哑铃相同重量的家用物品并不意味着它具备

与哑铃相同的重量并不必然意味着它具有正确的把手能够支撑安全且正确执行的举重锻炼以避免受伤。与此同时，另一位参与者 (P03) 分享了在家中很难找到两件重量完全相同的物品来充当两只哑铃

以便同时举起以提高时间效率和平衡。

尽管参与者对家居物品提出了许多建议用于举重时，参与者发现更没想到其他锻炼种类的替代品。部分参与者讨论了在没有阻力带的情况下使用一件衣物

或弹性带：P11：“我想你或许可以使用衣物，比如回收一些你不介意的衣物，比如旧袜子”类似地，另一名参与者 (P20) 补充说弹性腰带里的松紧带可以绑在门上，拉伸后用于特定锻炼。一位参与者 (P12) 分享了他们如何使用毛巾作为视觉引导线，在仰卧时锻炼腿部，例如让双腿能在毛巾上方和下方持续移动

另一位参与者 (P13) 讲述了他们如何尝试将床单绑起来挂在敞开的门上做引体向上，尽管参与者补充说这项锻炼是最难的锻炼之一试图复现。

对于非举重运动的另一个常见建议是使用家中的家具。一些参与者提到曾利用家具作为支撑来辅助锻炼。例如，一位参与者 (P11) 分享说椅子和墙可以

用于“拉伸神经或作为进行深蹲时的道具以增强稳定性，防止摔倒”。参与者补充说，家中一些物品可用于踏步或跳跃练习，例如床沿（或直接放在地板上的床垫）或其他表面如桌子和椅子。同样，固定装置也可作为锻炼时的支撑，比如“浴缸边缘”用于“深蹲”或“利用厨房桌边做俯卧撑” (P07)。

主题5：对家庭物品增强锻炼的偏好因人而异。我们发现两种关于利用家居物品增强锻炼的偏好类型

在增强现实环境中——将物品增强为类似健身器材以及其他个人激励物品。

物体增强以模拟健身器材，参与者共享的想法，如将桌子增强为健身平台或将水瓶增强为哑铃。一位参与者 (P19) 分享了如何通过将水瓶看起来像哑铃的选项，会让他们

“感觉更专业并激励[他们]进行更多锻炼”。另一位参与者 (P21) 指出，使用瓶子锻炼并不真正感觉像在锻炼，因此更倾向于对水瓶进行增强。为了使物体增强能模拟个人激励物品的效果，偏好包括将

水瓶或米袋增强成动物，或其他可能不寻常的东西，“与其本应呈现的样子完全不同，取决于使用者的个性”，比如“一个巨大的红色口红” (P19)。一位参与者建议将浴缸边缘和厨房餐桌分别增强为“一把可爱的椅子”和“一块非常大的石头” (P07)。还有人提议将米袋

增强为需要被抱起和拯救的宠物狗 (P08)。然而，部分参与者不喜欢在锻炼时使用具有‘个人激励’属性的增强物品这一概念：

参与者20：“首先，如果是狗的话.. 我就得担心它是否

hold carefully or not, it feels comfortable or not, so it's distracting me a bit. But for some people, maybe it's another thing. It's more like a motivation. So for me personally, I think I prefer gym equipment".

Theme 6: Augmenting the surrounding environment could enhance immersion. Participants discussed the importance of augmenting their home environment and not just the objects they use for exercise. For example, one participant mentioned augmenting a book rack to look like a gym rack, just to give the feel that they are in a gym to motivate them to exercise more: P04: "Let's say, a bookshelf? Can that be augmented into a rack filled with dumbbells? I can get the benefit of... psychologically, I'm inside gym and work out harder instead of being in the same apartment that I usually spend my day in. That'll be nice because, well, I guess if someone is using AR and they are being placed in a different environment compared to their own place, and still have the same benefits of working out in the gym." Another participant (P07) suggested augmenting their ceiling to look more interesting while they are lying down, as their room is small, narrow, and crowded: P07: "So, if with the AR glasses when I lie down maybe I can see the sunshine, the sea here, not in my bedroom, maybe I will feel happier and feel more fun about the exercise. My biggest problem as I mentioned, I don't want to exercise in the bedroom because it's just too crowded and I only have a bed and the desk. If the AR technology can let me see more things in the bedroom, change the environment, maybe [it] will make me more engaged". Augmenting the surrounding environment can not only increase immersion, but also help support some exercises. For example, a participant (P13) discussed the idea of using AR to create a visual "boundary on the floor" when exercising, "like a pseudo yoga mat ... to ensure you're not moving away from [the intended position]".

Theme 7: Home-based exercising could benefit from motivational elements beyond augmentation. Regardless of how well home objects and the surrounding environment are augmented, some participants wanted additional stimuli to motivate them to exercise at home. Some participants did not like, or were not interested in, exercising at home. Other than the lack of space at home, participants reported a lack of interest in exercising or wanting to use their home only as a space for relaxation. Participants revealed that some form of additional stimulus might help motivate them to try exercising at home. For example, some participants mentioned relaxing elements (e.g., a massage bed), while other participants preferred elements of fear: P08: "Maybe if you added a bit of a fear factor. So, if I'm lifting a rice bag for example, and if I don't lift it through enough reps, then I don't know, the floor becomes lava or I sink or something. I think anything fear inducing would really encourage me to exercise.". One participant (P21) provided an interesting example of how game elements can be included for exercising in AR, where they shared how they would like to obtain golden coins like in Super Mario Bros. [43] when jumping.

5 INSIGHTS FROM PHYSIOTHERAPISTS

We found two themes from our interviews with physiotherapists, related to the importance of tailoring home exercise programs to the evolving needs, abilities, and interests of each individual, and the variety of home objects that can be used for home exercises. We present each theme with supporting participant quotes.

Theme 1: Exercises need to be tailored to each person's evolving needs, abilities, and interests. Both physiotherapists emphasised that exercising at home needs to be highly personalised to the individual. First, exercises need to be tailored to focus on the person's needs and/or issues: S02: "*In our treatment we'll look at where their deficits are. So whether it's balance or strength or mobility or pain, and then just trying to give them something that is achievable. We'll usually practice it in the rooms here. So it's achievable for them, you know, at the time, but it's pushing them a little bit as well*". For example, balance training should be incorporated into a person's exercise program if they have issues around balance, which could help prevent falls. From the interviews, we found that both physiotherapists use the same software to prescribe exercise videos to patients: S01: "*We've got a snazzy bit of software called Physitrack, which is great because we can then assign them the exercises for them for their own personalised program and we can send it to the phone and we can track their progress and modify exercises easily*". One physiotherapist (S02) discussed the added benefit of having a video library of exercises that can be assigned to patients: S02: "*It's something we used to write it down on paper. So if they lost the paper, that's gone. So they can carry their exercises around on their phone with them because they download an app to view their exercises and there's a video of it showing the technique and we can write notes about their technique in it and how many we want them to do. And there are other feedback things so they can tick off when they've done their exercises, if they had any pain*".

Second, exercises should also be continuously tailored to the person's evolving abilities, not just based on their abilities at the start of the exercise program. People might have made some progress after some time exercising, or circumstances might have changed, requiring the exercise program to be adjusted. It is also important to ensure that the individual is appropriately challenged, without being required to overexert themselves. For example, one physiotherapist (S01) discussed how they individualise the GLA:D® (Good Life with Arthritis: Denmark) program [1] for people depending on how well they are doing and progressing. The other physiotherapist discussed the importance of timing: S02: "*Exercise that could cause some really bad pain one week, you know, three weeks later might be really good exercise for them. So, you know, trying to just pitch the exercise at the right level for their strength and stage of where they're at. So yeah, they should be really personalised to each individual patient. And I guess that's a big part of our role in training and it's trying to get that match between where they're at and what will push them a little bit further and help them without going too far and making them sore*".

Finally, exercises should be tailored to the individual's personal interest in order to increase motivation. Both physiotherapists discussed how a big part of their role is getting to know their patients, not only in terms of abilities, but also interests. One physiotherapist described how they approach tailoring exercises to patient interests: S01: "*We usually ask people, what is it you like to do? You know, if you like to garden then using the pots and things that you're filling and picking them up repeatedly, they're good resistance exercise*". The other physiotherapist shared the importance of aligning exercises with patient interests: S02: "*The focus will shift depending on their abilities and their interests as well. So, someone with no interest in sport may not want to do a running thing as an exercise, whereas*

增强家庭锻炼环境

需要小心抱持或是否感觉舒适, 这让我有点分心。但对某些人来说, 可能情况不同。它更像是一种动机。所以对我个人而言, 我认为我更喜欢健身器材"。

主题6: 增强周围环境可以提升沉浸感。 参与者们讨论了增强家庭环境而不仅仅是他们用于锻炼的物体重要性。例如, 一位参与者提到将书架增强为健身架的样子, 只是为了营造一种置身健身房的感觉, 从而激励他们更多地锻炼: 参与者04: "比如说, 一个书架? 能不能把它增强成一个装满哑铃的架子? 这样我就能获得.....心理上的好处, 感觉自己是在健身房内更努力地锻炼, 而不是整天待在同一间公寓里。这会很棒, 因为, 嗯, 我想如果有人使用AR技术, 他们被放置在一个与自己住所不同的环境中, 同时还能获得在健身房锻炼的相同益处。" 另一位参与者 (P07) 建议增强他们的天花板, 使其在躺下时看起来更有趣, 因为他们的房间狭小、拥挤: P07: "所以, 如果戴上增强现实眼镜躺下时, 也许我能看到阳光、大海, 而不是我的卧室, 可能会感到更快乐, 对锻炼也更有兴趣。我最大的问题, 正如我提到的, 我不想在卧室锻炼, 因为那里太拥挤了, 只有一张床和书桌。如果AR技术能让我在卧室里看到更多东西,

改变环境, 也许[它]会让我更投入"。增强周围环境不仅能提升沉浸感, 还能辅助支撑某些锻炼动作。例如, 一位参与者 (P13) 讨论了利用增强现实锻炼时创建视觉 "地面边界" 的想法, "就像虚拟瑜伽垫...以确保你不会偏离[预设位置]"。

主题7: 居家锻炼可受益于超越环境增强的激励元素。无论家居物品和周边环境被增强得多么完善,

部分参与者仍需要附加刺激来激励他们在家锻炼。有些参与者不喜欢或对居家锻炼不感兴趣。除了家中空间不足外,

参与者报告称缺乏锻炼意愿, 或仅希望将家作为放松空间。参与者透露某种形式的附加刺激可能有助于激励他们尝试居家锻炼。例如, 部分参与者提到放松元素 (如按摩床), 而其他参与者偏好恐惧元素: P08: "或许可以加入些恐惧因素。比如当我举米袋时, 如果没完成足够次数, 地面就会变成岩浆或让我下沉之类的。我觉得任何能引发恐惧的元素都能真正激励我锻炼。" 一位参与者 (P21) 提供了如何将游戏元素融入增强现实锻炼的有趣范例, 他分享了如何像《超级马里奥兄弟》那样[43] 在跳跃时{v2}获取金币。

来自物理治疗师的5大洞察

通过物理治疗师访谈, 我们发现了两个主题, 涉及根据每个人不断变化的需求、能力和兴趣定制家庭锻炼计划的重要性, 以及可用于家庭锻炼的各种家居物品。

我们通过参与者引述来呈现每个主题。

主题1: 锻炼需要根据每个人不断变化的需求、能力和兴趣进行个性化定制。 两位物理治疗师都强调, 在家锻炼需要高度个性化。首先, 锻炼需要针对个人的需求和/或问题进行定制: S02:

"在我们的治疗中, 我们会关注他们的不足之处。无论是平衡、力量、活动能力还是疼痛, 然后尽量给他们一些可实现的内容。"

"我们通常会在诊室里先进行练习。这样对他们来说既具有可行性, 同时也能适度地推动他们进步。" 例如, 若患者存在平衡问题, 就应在其锻炼计划中加入平衡训练, 这有助于预防跌倒。访谈显示, 两位物理治疗师使用相同软件为患者开具锻炼视频处方: S01: "我们有一款名为Physitrack的出色软件,

它很棒, 因为我们可以据此为他们分配个性化计划中的锻炼动作, 发送到手机端, 还能追踪进展并轻松调整锻炼内容。"

其中一位物理治疗师 (S02) 谈到可分配给患者的锻炼视频库的额外优势: S02: "过去我们只能写在纸上。如果他们弄丢了纸张,

这个问题已经解决了。因此他们可以通过手机携带锻炼计划, 因为他们下载了一个应用程序来查看锻炼内容, 里面有展示技巧的视频, 我们可以在其中记录关于他们技巧的笔记以及我们希望他们完成的次数。还有其他反馈功能, 比如他们可以在完成锻炼后打勾标记, 如果有任何疼痛也可以记录。

其次, 锻炼计划还应持续根据个人不断变化的能力进行调整, 而不仅仅基于他们在锻炼计划开始时的能力。经过一段时间的锻炼, 人们可能已经取得了一些进展, 或者情况可能发生了变化,

这就需要调整锻炼计划。同样重要的是确保个体受到适当的挑战, 而不会被迫过度劳累。例如, 一位理疗师 (S01) 讨论了如何根据个体的表现和进展个性化调整GLA:D® (丹麦关节炎患者的生活质量) 计划[1]。另一位理疗师则强调了时机的重要性: S02: "可能会导致严重疼痛的锻炼, 可能在几周后对他们来说是非常好的锻炼。所以, 你知道, 要尝试根据他们的力量和当前阶段将锻炼调整到合适的水平。是的, 这些锻炼应该针对每位患者进行个性化定制。我想这是我们培训工作中很重要的一部分, 就是努力在他们当前的状态和能够推动他们更进一步、帮助他们但不会过度导致疼痛的锻炼之间找到平衡。"

最后, 锻炼应根据个人兴趣进行定制, 以提高动机。两位物理治疗师都讨论了他们角色中很重要的一部分是了解他们的患者, 不仅是在能力方面, 还包括兴趣。一位物理治疗师描述了如何根据患者兴趣来定制锻炼:

S01: "我们通常会问人们, 你喜欢做什么? 你知道, 如果你喜欢园艺, 那么反复使用你装满和拿起的花盆等物品, 这些都是很好的抗阻训练"。另一位物理治疗师分享了将锻炼与患者兴趣相结合的重要性: S02: "重点会根据他们的能力和兴趣而转移。因此, 对运动没有兴趣的人可能不想把跑步作为一种锻炼方式, 而

for other people that are, you know, that's what they're trying to get back to. So it's really trying to get as close a match to that person and their interests as we can. I think that a really important thing as a physio is knowing your patient". They further explained the balance between needs and interests and the impact on patient motivation. For example, although "exercises in the water" may be beneficial, it is "completely inappropriate" for people who "don't want to get their body wet" (S02).

Theme 2: Home objects can be used as alternatives to exercising tools. There are small, affordable tools that physiotherapists might ask their patients to use for exercising at home, such as elastic bands or pulley systems. However, there are times when a patient is in a location without these specialised tools or they might prefer not to spend extra money to purchase these tools. In such cases, the patient can consider using household items as a 'good-enough' replacement. For example, the TheraBand [2] is a colour-coded elastic band used for resistance exercises that can be attached to a door for exercising (S01). A patient who did not bring their TheraBand on vacation but who still wants to exercise could consider another elastic band, like "bungee cords" or "luggage ropes/straps" (S02). Another example is a pulley system that can be used for shoulder injury-related exercises, which can be replicated using "a towel over a door frame", although "it's not as smooth" (S01).

During the interviews, both physiotherapists discussed how common household items can be used for exercising, such that people "don't have to go and buy equipment and use what's already in their house" (S01). One physiotherapist (S02) said that they ask their patients what they have at home, to discuss what they can use for exercising. Both physiotherapists shared a variety of household items that can be used for exercising and how they can be used. Water bottles, cans, or a bag of rice from the kitchen can be used as weights. Items that are non-breakable with the weight written on them (e.g., a can of soup) are useful and can also help the patient get a better sense of how much weight they are lifting to target the amount of weight they want to lift. Cushions can be used for balance practice, for example, by standing on a cushion on one leg while trying to do another task people normally do at home (dual-tasking), such as putting out the washing (S01). As part of an exercise routine, household items can also be used to self-massage. For example, soccer ball or glasses case can be used for self-massage, instead of foam rollers (S02).

Furniture works well as a support for exercising. Both physiotherapists provided examples where patients could use the back of a couch for stretching (S02), a chair for squatting exercise (S02), or a settee to be in a comfortable position for sit-ups or pelvic lifts (S01), or as balance support (S02). Furniture can also be used to practice "getting on and off the floor" (S01). Household fixtures like stairs can also be used for exercising. For example, stepping up and down a stair can be done as a knee exercise and to improve coordination and strength (S02). One physiotherapist (S02) even noted that people who are handy with wood might make their own appropriately-sized step, depending on their needs and desired challenge.

6 DISCUSSION

Our research aimed to investigate how AR HMDs can be used to facilitate more engaging, motivating, and personalised exercising at home. We conducted semi-structured interviews with 17 potential users and two senior physiotherapists. Together, our studies provided multi-source insights into home exercising in AR, taking into account different requirements and considerations. We present our discussion organised into three categories of recommendations, in descending order of priority as the exercises (the use cases) must first be determined before deciding which home objects to augment and how to augment these home objects: (1) suitable home exercises in AR; (2) home objects to augment for exercising; and (3) approaches to augmenting the home for exercising. We additionally examine motivational elements that can be considered to transform augmented exercising into augmented exergaming.

6.1 Defining Suitable Home Exercises in AR

The first step to designing an engaging home exercising experience in AR is to determine the answers to our research question RQ1, "**what kind of exercises are suitable for homes in an AR environment?**". Overall, we found that although there is no single exercise program that is suitable for everyone, there are common recommendations that can be followed, each with equal importance. While recommendations 1 and 2 provide foundational guidance for home-based exercises in AR, it is equally important to maintain people's motivation over time through recommendation 3, and to ensure that the exercises are matched towards different people's requirements through recommendation 4.

- **Recommendation 1: Home-based exercises should be mostly stationary to avoid breaking objects at home, injuring the person, and disturbing others.** This includes exercises such as strength-based exercises, flexibility exercises, martial arts, or light aerobic activities.



Figure 2: Tai chi (a martial art) is an example of a suitable exercise that can be done at home in an AR environment.

- **Recommendation 2: Home-based exercises should use minimal special equipment to save cost and storage space.** For example, exercises only requiring the user's body or a yoga mat are preferred. This is to reduce the financial

对于其他人来说，你知道，这正是他们想要重新回归的。所以我们真的在努力尽可能接近那个人及其兴趣。我认为作为理疗师，了解你的患者是一件非常重要的事情”。他们进一步解释了需求与兴趣之间的平衡以及对患者动机的影响。

例如，尽管“水中锻炼”可能有益，但对于“不想弄湿身体”的人来说“完全不合适”（S02）。

主题2：家居物品可作为锻炼工具的替代品。物理治疗师可能会让患者在家锻炼时使用一些小型、经济实惠的工具，如弹性带或滑轮系统。然而，有时患者所在的地方没有这些专用工具，或者他们可能不愿意额外花钱购买这些工具。在这种情况下，

患者可以考虑使用家居用品作为“足够好”的替代方案。例如，TheraBand [2] 是一种颜色编码的弹性带，可用于抗阻训练，可固定在门上用于锻炼（S01）。一位未携带TheraBand度假但仍想锻炼的患者，可以考虑使用其他弹性带，如“松紧绳”或“行李绳/带”（S02）。

另一个例子是可用于肩部损伤相关锻炼的滑轮系统，虽然“不如原版顺滑”，但可以用“门框上的毛巾”来模拟（S01）。

在访谈中，两位物理治疗师都讨论了如何利用常见家用物品进行锻炼，这样

人们“不必特意购买设备，直接用家里现有的物品即可”（S01）。其中一位物理治疗师（S02）表示，他们会要求询问他们的患者家中有什么物品，讨论可以如何使用

进行锻炼。两位物理治疗师分享了多种家居用品可用于锻炼的方式及其具体使用方法。厨房里的水瓶、罐头或米袋可作为重量使用。标有重量且不易碎的物品（例如汤罐头）非常实用，也能帮助患者更好地了解他们举起的重量以达到目标。他们想要举起的重量。垫子可以用于平衡练习，例如，单脚站在垫子上。同时尝试完成另一项人们通常在家做的任务（双重任务），比如晾衣服（S01）。作为锻炼计划的一部分，家居用品也可用于自我按摩。例如，足球或眼镜盒可用于自我按摩，而不是使用泡沫轴（S02）。

家具作为锻炼的支撑物效果很好。两位理疗师都提供了患者可以使用家具背部进行锻炼的实例。

一张用于拉伸的沙发（S02），一把用于深蹲练习的椅子（S02），或者一张长椅，用于保持仰卧起坐或骨盆提升的舒适姿势（S01），或作为平衡支撑（S02）。家具也可用于练习“上下地板”（S01）。家用固定装置像楼梯也可以用于锻炼。例如，踏步上下楼梯可以作为一种膝盖练习，同时有助于提升能量消耗。

协调性与力量（S02）。一位物理治疗师（S02）甚至注意到那些擅长使用木材的人可能会自己制作根据他们的需求和期望，拥有合适尺寸的台阶挑战。

6 讨论

我们的研究旨在探讨如何利用增强现实头戴显示器（AR HMDs）促进更引人入胜、激励性和个性化的在家锻炼。我们与17位潜在用户及两位资深物理治疗师进行了半结构化访谈。综合研究结果，我们获得了关于增强现实中家庭锻炼的多源洞察，并兼顾了不同需求和考虑因素。本文将讨论内容归纳为三类建议：

按照优先级降序排列，因为必须首先确定锻炼（用例），然后才能决定增强哪些家居物品以及如何增强这些家居物品：(1)适合家庭的AR锻炼；(2)用于锻炼的可增强家居物品；(3)增强家庭锻炼环境的方法。我们还研究了可以将增强锻炼转化为增强型运动游戏的激励元素。

6.1 定义适合家庭的AR锻炼

设计引人入胜的家庭锻炼体验的第一步

在增强现实中，是确定我们研究问题RQ1的答案，“什么样的锻炼适合在增强现实中的家庭环境”环境？”。

总体而言，我们发现虽然并不存在一种适合所有人的通用锻炼计划，但存在若干具有同等重要性的常见建议可供遵循

尽管建议1和2为

增强现实中的居家锻炼提供了基础指导，但通过建议3长期维持人们的动机，以及确保锻炼内容能适配不同人群的需求，具体可参照建议4。

- **建议1：居家锻炼应以静态动作为主，避免损坏家中物品、造成人身伤害或打扰他人。**适宜动作包括力量训练、柔韧性练习、武术或轻度有氧运动。



图2：太极（一种武术）是适合在增强现实环境中进行的居家锻炼范例。

- **建议2：居家锻炼应使用最少特殊设备以节省成本和存储**

空间。例如，仅需用户自身身体的锻炼上的

barriers to exercising and especially relevant for people living in smaller homes.



Figure 3: Yoga is a suitable home-based exercise for an AR environment, as it requires minimal special equipment.

- **Recommendation 3: Home-based exercises should incorporate both structure and novelty to keep the individual engaged and motivated, which can be facilitated with a library of exercises with details of the relevant goal or expected outcome.** Exercises labelled with the outcome/goal can provide users with information on how they can tailor their exercise program and keep it interesting, while still retaining the desired benefits. This was inspired by the success of the library of exercise videos that physiotherapists use, and by our participants who changed the type of exercises they did during COVID-19, such that they can be done at home yet provide the same benefits as exercises they used to do in the gym. Following insights from the literature, allowing people to set, measure, and achieve their goals can facilitate engagement and increase their motivation towards engaging in the activity [49].
- **Recommendation 4: Home-based exercises should be individually tailored to the person's evolving needs, abilities, and interests.** This ensures that the exercise is not only tailored to the user's current physical and mental condition [6, 14, 34, 56], but also interesting and motivating for the user. Our theme on the importance of tailoring exercises to each person's evolving needs, abilities, and interests further signifies the importance of individual customisation from the literature. In addition to tailoring the game environment [56], the game narrative [56], and the amount of guidance provided based on their level of expertise [30], future AR systems for home-based exercising and/or exergaming should individually customise the exercise based on people's evolving needs, abilities, and interest too.

6.2 Home Objects to Use and Augment for Exercising in AR

Insights from our literature review suggested that using tangible objects to facilitate home-based exercises in a virtual environment

can enhance the exercising experience, by providing users with immersive haptic experiences that matched the immersive audio and visual outputs of the system [27]. Our interviews with both types of participants revealed that different home objects can be used for different exercises. As different objects have different features and potential functionalities for exercising, the 'right' home object is dependent on the exercise the user wants to do. This finding supports previous literature that highlights the importance of carefully considering the specific use-cases before deciding what physical objects can be augmented to facilitate home exercising/exergaming [27]. In relation to the first part of our research question RQ2, "**what home objects can be augmented to facilitate exercising?**", we proposed the following recommendations:

- **Recommendation 5: Light to moderately-heavy objects, such as water bottles and cans, can be used for weightlifting exercises at home.**
- **Recommendation 6: Furniture, such as tables and chairs, can be used as support for exercising.**
- **Recommendation 7: Elastic objects, such as stocking or luggage rope, can be used for resistance-type exercises.**

Our findings add to the literature by specifying the list of tangible home objects that designers and researchers can consider to facilitate home-based exercising/exergaming through AR HMDs. These findings also support the theme of device augmentation reported by Knierim et al. [32], where participants discussed their desire to use AR to improve or add new functionalities to existing devices or home artefacts that are already well-integrated into the home environment. However, not every home object can be used for exercising. For example, although there were discussions on using heavier objects (e.g., rice bag) for weightlifting, there were concerns about the safety and feasibility of the exercise. Additionally, home objects will not always be as effective as exercise tools and equipment (e.g., using a towel over a door frame versus a proper pulley system). Therefore, it is important to set the level of expectation of users when using home objects to exercise at home. Where necessary, small, affordable specialised tools can be purchased, ensuring that the individual can exercise more effectively without compromising cost and storage space. For example, a proper elastic band costs around \$10 and they take up almost no space at home. Thus, in relation to the first part of our research question RQ2, we add one more recommendation:

- **Recommendation 8: If necessary, small, affordable specialised equipment can be purchased for more effective exercising.**

6.3 Augmenting the Home for Exercising

In relation to the second part of our research question RQ2, "**how can home objects be augmented?**", augmentation depends on the home objects being used and the exercises being done. We found that preferences vary between individuals, but two general recommendations can be made:

- **Recommendation 9: Home objects can be augmented into their equivalent exercising tools or equipment, or other personally motivating objects, depending on the user's preference.** For example, a water bottle can be augmented to look like a dumbbell for weightlifting activities

锻炼障碍, 对特定人群尤为重要
居住在小户型住宅。



图3：瑜伽是一种适合居家的增强现实锻炼方式环境，因为它需要最少的专用设备。

- **建议3：居家锻炼应兼顾结构和新颖性，以保持个体的参与度和积极性，这可通过配备详细目标或预期成果的锻炼动作库来实现。标注了成果/目标的锻炼能为用户提供如何定制其锻炼计划并保持趣味性的信息。**

同时仍保留所需的益处。这一灵感来源于理疗师使用的锻炼视频库的成功案例，以及我们的参与者在新冠肺炎期间改变锻炼方式的做法，使得这些锻炼可以在家完成，同时提供与健身房锻炼相同的益处。根据文献中的洞察，

允许人们设定、衡量并实现他们的目标可以促进参与度，并提高他们参与活动的动机[49]。

- **建议4：居家锻炼应根据个人不断变化的需求进行个性化定制，**

能力与兴趣。这确保了锻炼不仅适应用户当前的身心状况[6, 14, 34, 56]，还能对用户产生吸引力和激励性。我们关于根据每个人不断变化的需求、能力和兴趣定制锻炼的重要性的话题，进一步印证了文献中个性化定制的重要性。除了根据用户的专业水平定制游戏环境[56]、游戏叙事[56]，以及提供的指导量[30]外，未来用于居家锻炼和/或运动游戏的增强现实系统也应基于人们不断变化的需求、能力和兴趣进行个性化锻炼定制。

6.2 可使用的家居物品及其增强功能 增强现实中的锻炼

我们的文献综述表明，使用有形
在虚拟环境中促进居家锻炼的物理对象

能够通过为用户提供与系统沉浸式音频和视觉输出相匹配的沉浸式触觉体验[27]，从而增强锻炼体验。我们对两类参与者的访谈显示，不同的家居物品可用于不同的锻炼项目。由于不同物品具有不同的特征及锻炼相关潜在功能，'合适的'家居物品取决于用户想要进行的锻炼类型。这一发现支持了先前文献的观点，即在决定哪些物理对象可被增强以促进家庭锻炼/运动游戏[27]之前，必须仔细考量具体用例的重要性。针对我们研究问题RQ2的第一部分——'哪些家居物品可被增强以促进锻炼？'，我们提出以下建议：

- **建议5：轻至中等重量的物品，如水瓶和罐头，可用于在家进行举重锻炼。**
- **建议6：家具，如桌子和椅子，可作为锻炼时的支撑使用。**
- **建议7：弹性物品（如长袜或行李绳）可用于抗阻锻炼。**

我们的研究通过明确列出具体家居物品清单，补充了现有文献，这些物品可供设计师和研究人员考虑，以通过增强现实头戴显示器促进居家锻炼/运动游戏。

这些发现也支持了Knierim等人[32]，报告的设备增强主题，其中参与者表达了他们希望使用增强现实来改进或为已良好融入家庭环境的现有设备或家居用品增添新功能的愿望。然而，并非所有家庭物品都适合用于锻炼。例如，尽管有关于使用较重物品（如米袋）进行举重的讨论，但也存在对该锻炼安全性和可行性的担忧。此外，家居物品的效果并不总能媲美专业锻炼工具和设备（例如在门框上挂毛巾与使用专业滑轮系统的对比）。因此，设定用户对使用家居物品进行居家锻炼的期望值非常重要。必要时，可购买小型、经济实惠的专用工具，确保个人既能更有效地锻炼，又不会增加成本和占用存储空间。例如，一条专业弹性带价格约10美元，且几乎不占用家居空间。

因此，针对我们研究问题RQ2的第一部分，我们补充一条建议：

- **建议8：如有必要，可购买小型、经济实惠的专业设备以提升锻炼效果。**

6.3 家居环境增强方案

针对我们研究问题RQ2的第二部分“**如何增强家居物品？**”，其增强方式取决于所使用的家居物品及进行的锻炼项目。我们发现偏好因人而异，但可以提出两条通用建议：

- **建议9：家居物品可被增强为等效的锻炼工具或设备，或其他个人激励物品，具体取决于用户偏好。例如，水瓶可被增强为类似哑铃的外观以用于举重活动**

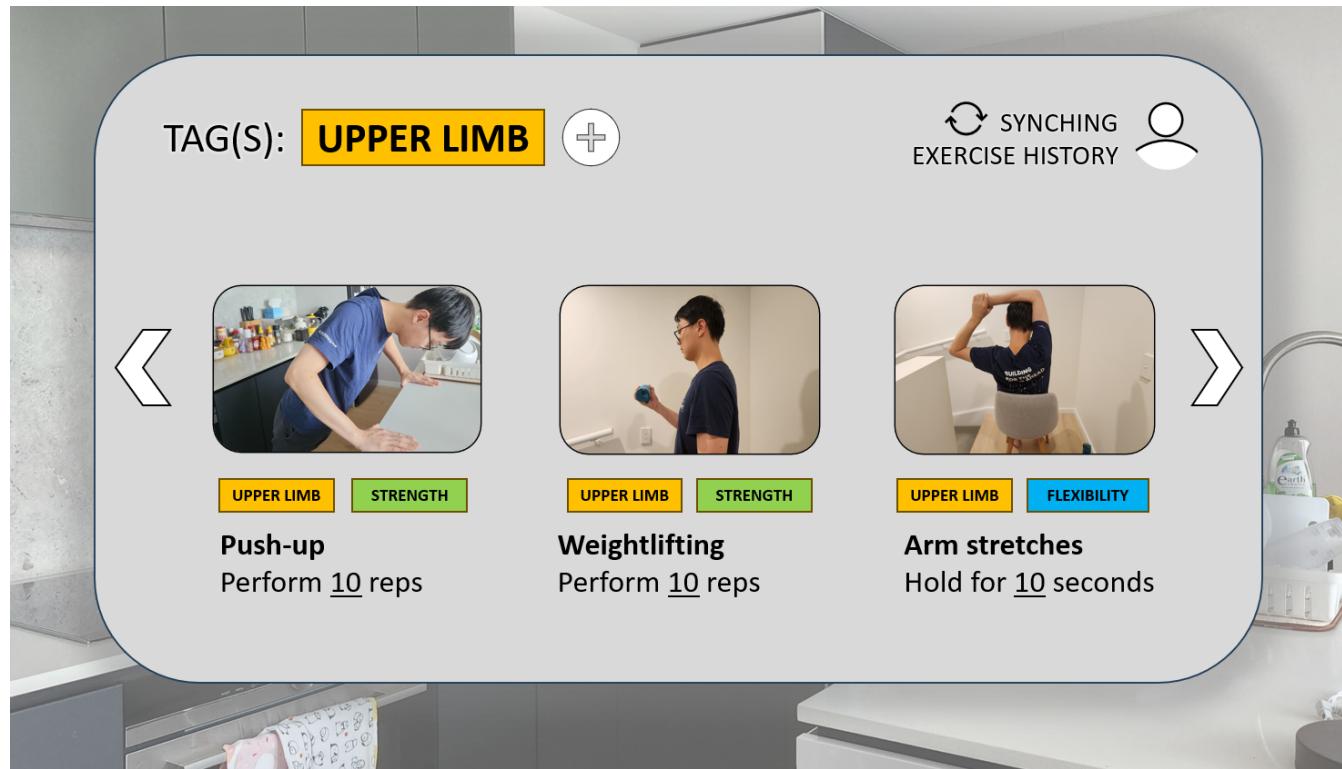


Figure 4: Illustration: A library of exercise in AR that allows users to tailor their exercise based on their desired goals and current progress.

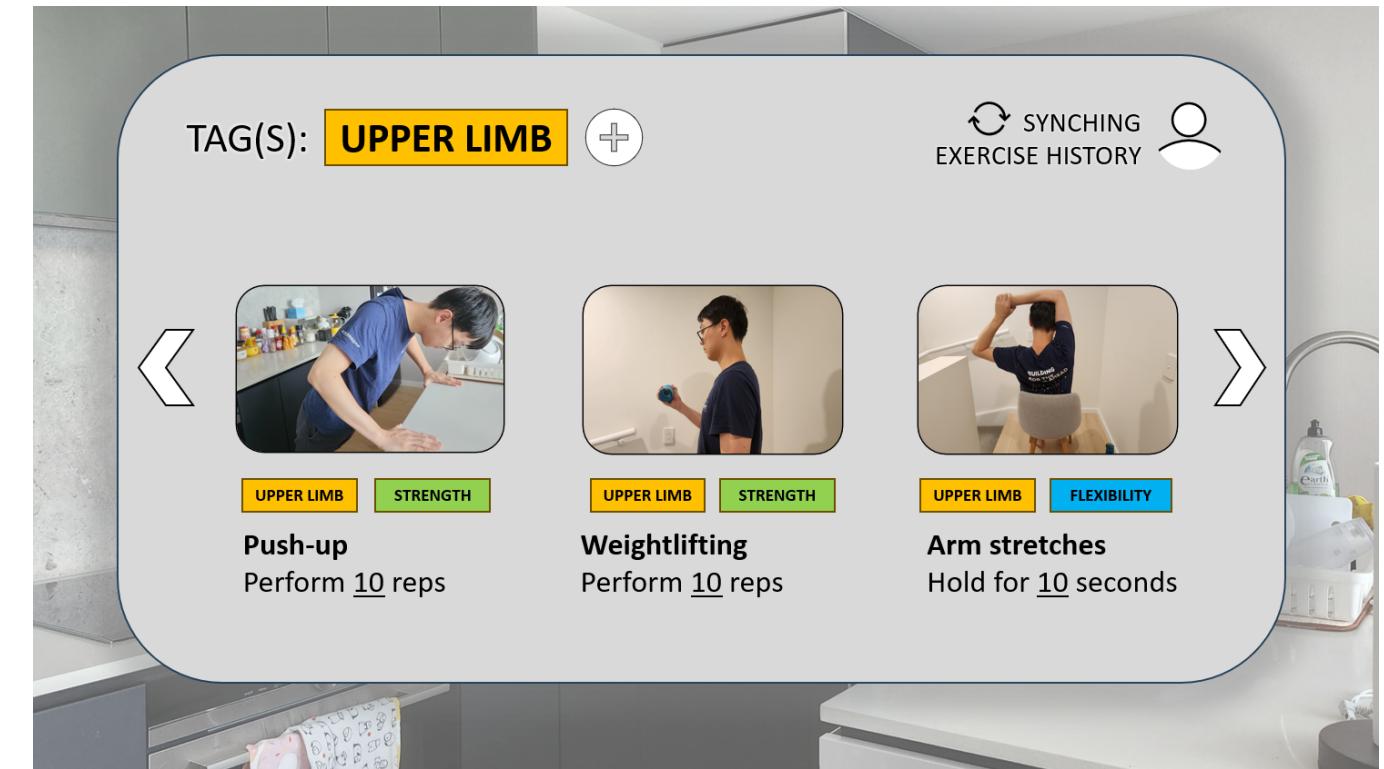


图4：插图：一个增强现实中的锻炼库，允许用户根据他们的期望目标和当前进度。

at home, or other personally motivating objects, such as a pet. Some participants also shared that augmenting household items into their equivalent exercising tools or equipment can replicate the feeling of being in a gym, which motivates them to exercise. The different user preferences again suggests the importance of individual customisation. This may be related to results from [56], where preference for sports environment was only associated with high intrinsic motivation, but not low intrinsic motivation. When designing an AR system for exercising at home, there should be a variety of options for object augmentation.

- **Recommendation 10: Nearby home objects not directly used for exercising can still be augmented to further enhance immersion for exercising, but the home environment should not be over-augmented.** For example, not only should the water bottle be augmented into a dumbbell or a pet, but the nearby bookshelf can be augmented into a gym rack or into other personally motivating objects (see Figure 5). It is important to remember that although augmenting home objects and environments can enhance the home exercising experience, over-augmenting could lead to information and cognitive overload among users as our senses are biologically limited [32]. Generating too much sensing input through AR can interfere with regular vision, which limits user perception [32]. Designers should carefully consider how additional stimuli can be combined with

naturally-perceived stimuli, without overloading the users [51]. Following the recommendations of Bonanni et al. [10], the quality and quantity of augmentation should also be tailored based on each task/exercise. While further work needs to be done to investigate how this can be achieved, findings from prior studies can serve as insights. For example, the shape and size [27] of the home object chosen for the exercise can be used to determine the shape and size of the virtual object being overlaid, to prevent a mismatch that would negatively affect the user's feeling of immersion and engagement [54].

6.4 Augmented Exercising to Exergaming

Our interviews with potential users revealed that home-based exercising could benefit from motivational elements beyond augmentation, including game elements and social elements. Some people simply do not like exercising at home or exercising in general (e.g., P02) and would need additional stimuli to motivate them to exercise. We also found that different people proposed different types of additional stimuli that could successfully motivate them to exercise. For example, participants talked about having a progress bar that keeps track of how many push ups they have done in comparison with the goal, a point system that tracks your ability and challenges you for the next day, or collecting golden coins while exercising in AR, just like how they would in Super Mario Bros. [43]. One physiotherapist (S01) also discussed the potential benefits of having

在家, 或其他个人激励物品, 例如宠物
一些参与者还分享说, 将家居用品增强为
等效的锻炼工具或设备可以
复现身处健身房的感觉, 以此激发他们的
锻炼动机。不同的用户偏好再次表明了
个性化定制的重要性。该可能与
[56]的研究结果相关, 其中对运动环境
的偏好仅与高内在动机相关, 而与
低内在动机无关。在设计增强现实系统时,
在家锻炼时, 应当提供多样化的
物体增强选择。

- **建议10：附近未直接用于锻炼的家居物品仍可被增强以进一步提升锻炼的沉浸感, 但家庭环境不应过度增强。例如,**

不仅可将水瓶增强为哑铃或宠物, 邻近的书架也可被增
强为健身架或其他个人激励物品(见图5)。需谨记,
虽然增强家居物品和环境能提升家庭锻炼体验, 但过度
增强可能导致用户信息和认知超载, 因为我们的感官存
在生物学限制[32]。通过增强现实生成过多感知输入可
能干扰正常视觉,

这限制了用户感知[32]。设计师应仔细考虑如何将附加刺激与

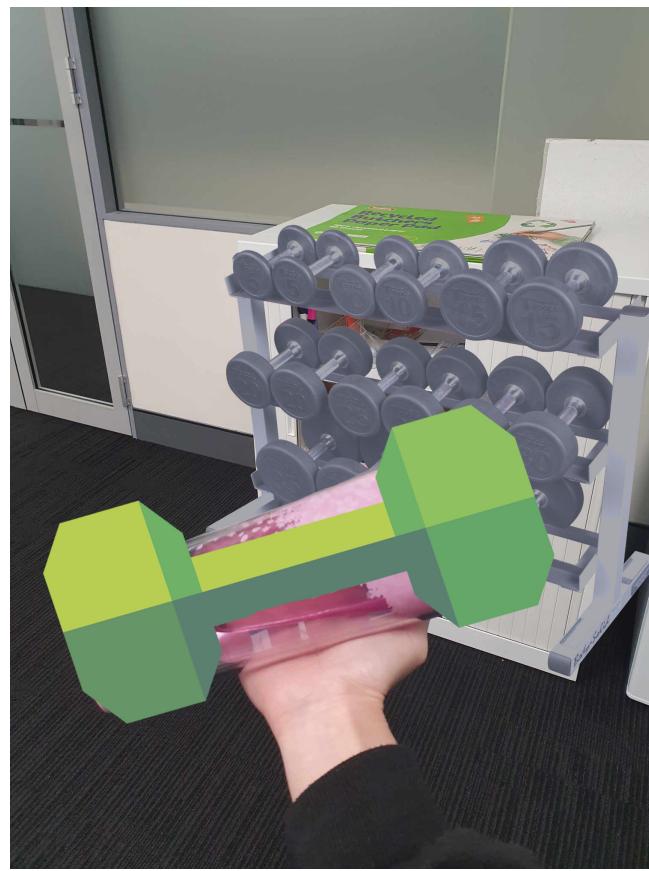
自然感知刺激相结合, 而不会让用户感到负担过重
[51]。遵循Bonanni等人[10]的建议
增强的质量和数量也需
根据每项任务/锻炼量身定制。虽然仍需进一步工作
来研究如何实现这一目标,
但先前研究的结果可作为洞察。例如, 所选家庭物品[27] 的形状和大小
可用于确定叠加虚拟物体的形状和大小,
对用户的沉浸感产生负面影响
参与度[54]。

6.4 从增强锻炼到运动游戏

我们与潜在用户的访谈显示, 居家锻炼除了增强功能外, 还可受益于游戏元素和社交元素等激励元素。有些人就是不喜欢在家锻炼或锻炼本身(例如, P02), 需要附加刺激来激励他们锻炼。我们还发现, 不同的人提出了不同类型的附加刺激, 这些刺激能成功激励他们锻炼。例如, 参与者们提到可以设置一个进度条来记录他们完成的俯卧撑数量并与目标进行比较, 或者采用积分系统追踪能力并挑战次日目标, 又或是在增强现实中锻炼时收集金币, 就像他们在《超级马里奥兄弟》[43]中那样。一位物理治疗师(S01)还探讨了引入



(a) A water bottle and a nearby book rack



(b) Augmenting the water bottle and nearby book rack

Figure 5: Illustration: Augmenting not only the water bottle, but also a nearby book rack to simulate weightlifting experience at home through AR.

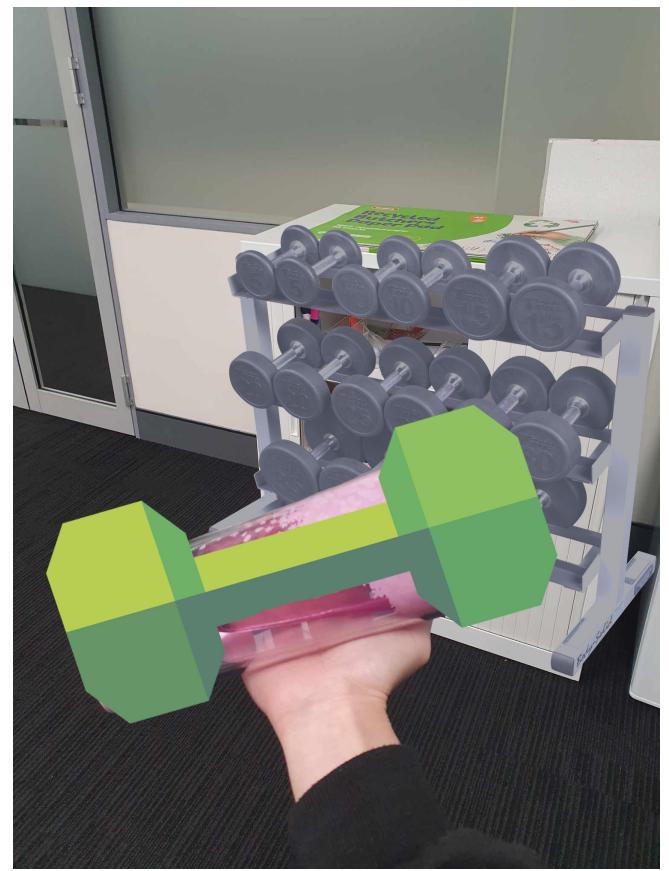
virtual people in an AR environment, including as a form of encouragement or peer-pressure to keep exercising, or even as a form of support to keep track of the progress of the exercise especially for people with memory problems. This insight adds to the results of previous work on the use of virtual coaches [34, 39, 56] in AR at home for exercising, by suggesting that virtual coaches can bring the additional benefits of further enhancing users' motivation and perception. These comments suggest the potential of gamification of home-based exercise programs, which needs to be explored in the context of exercising at home through AR. Although our results on the importance of additional motivational elements does not currently answer our initial set of research questions, they can be serve as an additional source of insights for future research aiming to transform AR exercising into AR exergaming, alongside the rich pool of previous research specifying different strategies for increasing motivation.

Prior research suggests that gamification can have a positive impact on exercise motivation [31]. Gamification elements such as points, leaderboards, levels, badges, competition, and cooperation have been used to promote physical activity in health context [3, 20, 40]. For example, points can be given to users for completing

different activities, which will be ranked in a leaderboard against other users to promote competition. Badges, as a form of rewards, can be given to users who have completed their goals. The inclusion of rewards can motivate people to be more physically active, for example as demonstrated in [17], where users of activity rewards programmes in South Africa (earning discounts/cashbacks for having 'active days') were more than twice as active than non-users. In the context of AR exergaming, similar gamification elements can be applied to increase people's motivation to exercise at home. For example, users can obtain points for completing exercises in real-time (e.g., one sit-up equals one point), which can also help them keep track of how many times they have done the exercise, especially if they have memory problems. The GameFlow model [59] identifies the importance of social elements to the enjoyment of video games, noting that people will play games for the social experience, even when they do not like games or the type of game being played. Social elements can enhance motivation to exercise, especially among older adults [56]. Similarly, for home-based exercises in AR, incorporating social incentives in the form of competition and/or cooperation can further increase people's motivation and willingness to exercise. For example, users can be grouped into teams to



(a) 水瓶与邻近书架



(b) 增强水瓶与邻近书架功能

图5: 插图：不仅增强水瓶功能，还利用邻近书架模拟举重体验通过增强现实技术在家实现。

虚拟人物到增强现实环境中的潜在益处，包括将其作为一种激励形式或同伴压力以坚持锻炼，甚至作为一种支撑来追踪锻炼的进展，尤其是对于有记忆问题的人群。这一见解进一步丰富了先前关于在增强现实中[34, 39, 56]使用虚拟教练在家锻炼的研究结果，表明虚拟教练还能带来额外益处：进一步提升用户的动机与感知。这些评论暗示了游戏化的潜力家庭锻炼计划的相关问题，这需要在通过增强现实在家锻炼的背景下进行探索。尽管我们的结果关于额外激励元素重要性的研究并未直接回答我们最初设定的研究问题，但它们可以作为未来研究的重要洞察来源，旨在将AR锻炼转变为AR健身游戏，同时结合先前研究中丰富的策略库，这些研究详细阐述了不同的提升动机。

先前的研究表明，游戏化可以对锻炼动机产生积极影响[31]。诸如积分、排行榜、等级、徽章、竞争和合作等游戏化元素已被用于在健康背景下促进体育活动[3, 20, 40]。例如，用户完成不同活动后可获得积分，

这些活动将在排行榜上进行排名对比。其他用户以促进竞争。徽章作为一种奖励形式，可授予完成目标的用户。引入奖励机制能激励人们更积极地参与体育活动，例如如[17]所示，参与活动奖励计划的南非用户（通过保持‘活跃天数’获得折扣/返现）的活动量是非用户的两倍多。

在AR健身游戏的情境中，类似的游戏化元素可以被应用于提升人们居家锻炼的动机。例如，用户可通过实时完成锻炼动作获取积分

（如完成一次仰卧起坐对应一个积分），这也能帮助他们记录已完成锻炼的次数，尤其适用于存在记忆问题的用户。游戏流模型[59]指出社交元素对视频游戏娱乐性的重要性，指出人们会为了社交体验而玩游戏，即使他们不喜欢游戏或正在玩的游戏类型。社交元素能增强锻炼动机，尤其对老年人[56]而言。类似地，在增强现实的居家锻炼中，融入以竞争和/或形式呈现的社交激励合作能进一步提升人们的动机和锻炼意愿。例如，可将用户分组为团队，

compete with each other (e.g., most rope-skips done as a team [20]) and the winning team can be provided with rewards, to encourage participation through peer-pressure. However, prior research also found that interest in the gamification aspect of exercises can decrease over time [17, 60]. Because novelty is an important cause of motivation [62], enjoyment can decrease when novelty of the gamification aspects wears off [60]. Therefore, designers should also investigate how novelty can be sustained for different gamification elements, to foster long-term engagement and motivation.

6.5 Ethical Considerations

While our interviews did not include any discussion about ethical considerations, we acknowledge that there are physical, privacy, social, and psychological concerns that need to be considered when developing AR applications [57]. Although physical concerns, including the risk of falling down, have been reduced by using AR instead of VR HMDs, they have not been completely eliminated. Notably, users can still experience dizziness [57] from the weight of the HMD. Privacy concerns can arise when using AR at home, as AR devices need to extensively sense and record the spatial information of the user's environment. In the case of this research, the environment is the user's home, which contains a variety of sensitive and personal information. In addition, users' health data recorded by the system is also at risk from being exposed and/or exploited. Participants from Knierim et al. [32] discussed their concern that AR devices would constantly record their actions, which threatened their privacy. In social settings, privacy concerns can arise when users share a physical space with other people while using AR devices, or when users remotely share virtual content with other users [50]. Non-users could be recorded without their consent, and being immersed in AR can lead to an absence of engagement with others in real time [57], triggering social concerns. In a shared AR environment, there can be issues relating to psychological ownership when virtual objects are augmented onto another user's body, belongings, or personal space [48].

In addition to our design recommendations, future AR systems should be designed in a way that respects the privacy of both users and non-users, is transparent about how they are protected (regarding data collection, use, sharing, and storage), and facilitates access control for shared virtual content [22, 32, 50]. AR interactions must also be designed to respect existing social structures and support social activity, especially in a shared environment [32]. Finally, initial design stages should include considerations on how issues relating to psychological ownership in shared AR can be handled, to create a safe, enjoyable, and productive shared AR environment [48].

6.6 Limitations and Future Work

There may be potential biases arising from the current pool of participants. As most participants from our pool of potential users were young adults, the needs and preferences of people from other age groups might be under-reported. Next, while our results suggest that augmentation needs to be personalised based on user preferences, there was a lack of insights provided by participants regarding the specific set of items that can augment home objects and how augmentation can be tailored to each task/exercise. This

is especially relevant for users who prefer augmenting home objects with personally motivating objects. Finally, we acknowledge that there is a risk of coder/experimenter bias as the studies were conducted and analysed by the first author.

Future work should also involve further interviews with more participants in relevant professions to gain more insights on how home objects and environments can be augmented to facilitate exercising. This can include exercise-related professionals (physiotherapists and professional trainers), experienced AR developers, exergame designers, and other stakeholders. The research could also be expanded to include AR exercising/exergaming in other locations, such as a gym, clinic, or physiotherapist's office. To gain further insights on the specific items that home objects can be augmented with, our ongoing work will incorporate a photo elicitation activity, inspired by Knierim et al. [32], and co-design workshops with participants to further brainstorm how home objects can be augmented. This combined participatory design approach will further contribute to the development of a set of design principles on how home objects and environments can be augmented for exercising. With an initial set of design principles, future research can investigate how game design principles can be incorporated to transform augmented exercising into augmented exergaming, building on our theme for motivational elements. The overall long-term goal of this ongoing research is to investigate how exergames can be designed for augmented home environments to lead to improved adherence and effectiveness of exercising at home and reduced barriers to exercising, transforming future exercises with AR technology and game design principles.

7 CONCLUSIONS

Exergames have the potential to increase people's motivation and adherence to exercise. Current exergaming systems could be made more accessible, inclusive, and immersive, with AR HMDs as one potential candidate. However, there is limited research investigating the design of such systems to promote exercising or exergaming at home. We conducted interviews with potential users and senior physiotherapists as the first step in understanding how homes can be augmented for exercising, to lay the foundation for future research into designing augmented home-based exergames. We developed 10 recommendations related to suitable home-based exercises, home objects, and augmentation, which can help guide future designers/researchers aiming to develop home-based exercising experiences using AR HMDs. Our results further contribute to the existing body of research on the use of AR for exercising, home applications, and everyday objects by presenting the first foundational study investigating the wide range of exercises that can be supported through AR HMDs in home environments and the different ways home elements may support these exercises, and laying the groundwork for future work developing home-based exergaming through AR HMDs to increase people's physical activity levels. While certain specialised equipment and tools for exercising cannot be easily replaced, our ongoing work to design exergames for home-based exercises using AR HMDs aims to create a more affordable, accessible, inclusive, and immersive way to exercise.

进行相互竞争（如以团队形式完成最多跳绳次数[20]），并为获胜团队提供奖励，通过同伴压力鼓励参与。然而，先前研究也发现，人们对锻炼游戏化的兴趣会随时间推移而减弱 [17, 60]。由于新颖性是动机的重要诱因[62]，当游戏化方面的新颖性消退时，乐趣可能降低[60]。因此，设计师还应研究如何为不同游戏化元素维持新颖性，以促进长期参与度和动机。

6.5 伦理考量

虽然我们的访谈未涉及任何关于伦理考量的讨论，但我们承认在开发增强现实应用时需要考虑物理、隐私、

社交和心理层面的问题[57]。尽管通过使用增强现实而非虚拟现实头戴设备，包括跌倒风险在内的物理隐患已有所降低，但尚未完全消除。

值得注意的是，用户仍可能因头戴式显示器的重量而产生头晕[57]。在家使用增强现实时也可能引发隐私问题，

由于增强现实设备需要广泛感知并记录用户环境的空间信息，在此研究中，

环境是用户的家，其中包含各种敏感与个人信息。此外，系统记录的用户健康数据也面临被暴露和/或利用的风险。Knierim等人研究中的参与者[32]表达了他们的担忧，认为增强现实设备会持续记录他们的行为，这威胁到了他们的隐私。在社交环境中，当用户与他人共享物理空间并使用增强现实设备时，或当用户远程与其他用户共享虚拟内容[50]时，隐私问题可能浮现。非用户可能在未经同意的情况下被记录，而沉浸于增强现实中可能导致无法实时与他人互动[57]，从而引发社交顾虑。

在共享增强现实环境中，当虚拟物体被增强到其他用户的身體、物品或个人空间[48]时，可能会出现与心理所有权相关的问题。

除了我们的设计建议外，未来增强现实系统应以尊重用户与非用户隐私的方式设计，并透明展示其保护机制（涉及数据收集、使用、共享及存储），同时便于对共享虚拟内容{v1}实施访问控制。增强现实交互的设计还须遵循现有社会结构，还必须设计得尊重现有的社会结构支撑社交活动，尤其是在共享环境[32]中。最后，初始设计阶段应考虑如何在共享增强现实中处理与心理所有权相关的问题，以创造一个安全、愉快且高效的共享增强现实环境[48]。

6.6 局限性与未来工作

当前的参与者群体可能存在潜在偏见。由于我们潜在用户池中的多数参与者是年轻人，其他年龄组人群的需求和偏好可能未被充分报告。其次，虽然我们的结果表明增强需要根据用户偏好进行个性化定制，但参与者未能提供关于具体哪些物品可增强家居物品以及如何针对每项任务/锻炼定制增强的洞察。

这对于偏好用个人激励物品增强家庭物品的用户尤为相关。最后我们承认

由于研究存在编码者/实验者偏见的风险，且由第一作者进行和分析。

未来工作还应包括与更多相关职业的参与者进行进一步访谈，以获取更多关于如何增强家居物品和环境以促进锻炼的洞察。这可能包括运动相关专业人士（物理治疗师和专业教练）、经验丰富的AR开发人员、

运动游戏设计师及其他利益相关者。研究还可扩展至包含其他场所的AR运动/运动游戏，如健身房、诊所或物理治疗师办公室。为深入探究家居物品可增强的具体物品，我们正在进行的工作将借鉴Knierim等人[32]的方法，结合照片启发活动及与参与者共同设计研讨会，进一步集思广益如何增强家居物品。这种结合的参与式设计方法将进一步推动制定一套关于如何增强家居物品和环境以支持锻炼的设计原则。基于初步设计原则，未来研究可探索如何融入游戏设计原则，将增强锻炼转化为增强型运动游戏，

基于我们对激励元素的主题延伸。这项持续研究的总体长期目标是探索如何为增强家庭环境设计运动游戏，以提高在家锻炼的坚持度和效果，减少锻炼障碍，并通过AR技术和游戏设计原则改变未来的锻炼方式。

7 结论

运动游戏具有提升人们锻炼动机的潜力，并增强锻炼的坚持度。当前运动游戏系统可以设计得更易于使用、更具包容性和沉浸感，其中增强现实头戴显示器是一个潜在候选方案。然而，目前针对这一领域的深入研究仍显不足。此类系统的设计旨在促进锻炼或运动游戏在家。我们通过访谈潜在用户和资深物理治疗师作为第一步，以理解家庭环境

如何被增强以支持锻炼，为未来研究设计基于家庭的增强型运动游戏奠定基础。我们提出了10条建议，涉及适合的居家锻炼、家居物品及增强技术，这些建议可指导

未来设计师/研究人员开发基于家庭的锻炼体验，使用增强现实头戴显示器。我们的结果进一步贡献

针对现有关于使用增强现实进行锻炼的研究成果，家庭应用及日常物品的研究，我们首次提出了一项基础研究，探讨了在家庭环境中通过增强现实头戴显示器可支持的广泛锻炼方式，以及家庭元素可能支撑这些锻炼的不同方式。并为未来工作奠定基础，开发基于增强现实头戴显示器的居家运动游戏以提升人们的体育活动水平。等级。虽然某些专业设备和锻炼工具无法轻易替代，但我们正在设计运动游戏用于居家锻炼，利用增强现实头戴显示器，旨在创造一种更经济实惠、易于使用、包容性且沉浸式的锻炼方式。

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