SoleMate: A Detection and Reminder App to Reduce Sedentary Behaviour At Home

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Abstract

Prolonged sitting can lead to serious physical and mental health problems. However, current intervention studies predominantly focus on workplace sedentary behaviour, neglecting its prevalence at home. To address this, we conducted a mixed-method study with a diary study (5 participants), an online questionnaire (56 responses), and interviews (5 participants). Our findings revealed a lack of motivation and awareness about the long-term risks of sedentary behaviour. Participants expressed a desire for real-time data and non-invasive, engaging reminders. Using an iterative design process, we created SoleMate, an app featuring contextual reminders, a customisable avatar, educational quizzes, data visualisation and data-monitoring slippers. In controlled experiments with 11 participants, combined with Nielsen's 10 usability heuristics, users found context-aware reminders ineffective but appreciated educational interactions through the avatar and the slippers' ability to track sitting time. Based on feedback, we added gradual reminders with exercise guidance from the avatar and a monthly history of sitting data. Aligned with Sustainable Development Goal 3: Health and Well-being, SoleMate integrates non-invasive live tracking with an engaging avatar interface to promote healthier habits and long-term behaviour change.

CCS Concepts

• **Human-centred computing** · **Human computer interaction (HCI)** · **Interaction design**;

Keywords

Sedentary behaviour; behavioural change; home

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1 INTRODUCTION

Sedentary behaviour, characterised by low-energy activities (1.5 METs or less) like sitting or lying down [19], affects over 40% of adults in desk jobs or with high screen time [14]. Dubbed "the new smoking" [20], it is linked to health risks such as obesity [7], cardiovascular disease [3], premature death [10], and other adverse outcomes [3, 6, 10]. Addressing sedentary behaviour can help prevent these illnesses while improving overall health, thereby contributing to the achievement of the Sustainable Development Goal (SDG) 3, which includes reducing premature mortality from non-communicable diseases, promoting healthy lifestyles, and achieving universal health coverage [13].

Sedentary behaviour occurs across various settings, including workplaces, schools, and homes - among these, the home environment accounts for a substantial proportion, a trend exacerbated by lifestyle changes during the COVID-19 pandemic [9, 16]. While its health risks are widely recognised, limited research has focused on sedentary behaviour within home settings, leaving a significant gap in understanding [15]. Thus, the present study aims to design innovative, home-specific approaches to reduce sedentary behaviour effectively. Our main research is: How to design interactive technologies to reduce adults' home sedentary behaviour? To investigate this overarching question, we focused on two sub-questions as follows: 1) What are people's barriers to reducing current sedentary behaviour at home? 2) What are people's needs in addressing sedentary behaviour through technology at home?

To answer our research questions, we conducted a seven-day diary study focusing on 5 existing sedentary-improving Apps, the surveys with 56 responses and interviews with 5 participants to explore sedentary behaviour. Users showed low motivation to reduce sedentary behaviour and limited awareness of its long-term harms or reduction strategies. Our findings emphasised the need for non-invasive, emotionally-driven solutions that provide clear knowledge, engaging reminders with minimal disruption, and accurate data. To address these needs, we proposed and improved the design based on user testing, and finally developed SoleMate, a wearable slipper sensor paired with a desktop avatar app with non-invasive alerts, educational content, and data visualisation. SoleMate aims to unobtrusively detect prolonged sitting through

SoleMate：一款减少家庭久坐行为的检测与提醒应用

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摘要

长时间久坐可能导致严重的 身心健康问题。然而，现有干预研究主要集中于 工作场所 久坐行为，忽视了其在 家庭 中的普遍性。为此，我们开展了一项 混合方法研究，包含 日记研究（5名 参与者）、在线问卷（56份回复）及 访谈（5名 参与者）。研究发现，人们普遍 缺乏动力 且对 久坐行为 的长期风险认知不足。参与者表达了对 实时数据 和 非侵入式、互动提醒 的需求。通过迭代设计流程，我们开发了SoleMate应用，其功能包括 情境提醒、可定制虚拟形象、教育性测验、数据可视化 及 数据监测拖鞋。在11名 参与者 的 对照实验 中，结合 尼尔森十大可用性原则，用户认为 情境感知提醒 效果有限，但赞赏通过虚拟形象实现的 教育性互动 以及 拖鞋 追踪久坐时间 的能力。根据反馈，我们新增了虚拟形象提供的 渐进式提醒 与 运动指导，以及 坐姿数据 的 月度历史记录。SoleMate 符合 可持续发展目标3：健康与福祉，通过整合 非侵入式实时追踪 与 互动虚拟形象界面，旨在培养 更健康的习惯 并实现 长期行为改变。

CCS概念

. 人本计算 · 人机交互（HCI） · 交互设计;

关键词

久坐行为; 行为改变; 家庭

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1 引言

久坐行为以低能耗活动（1.5代谢当量或更低）为特征，如静坐或躺卧 [19], ，影响着超过40%从事案头工作或长时间屏幕使用的成年人 [14]。被称为“新式吸烟” [20], ，它与肥胖 [7], 、心血管疾病 [3], 、过早死亡 [10], 等健康风险及其他不良后果 [3, 6, 10]相关。解决久坐行为有助于预防这些疾病，同时提升整体健康水平，从而助力实现可持续发展目标3（SDG 3）——包括降低非传染性疾病导致的过早死亡率、促进健康生活方式及实现全民健康覆盖 [13]。

久坐行为发生在多种环境中，包括工作场所、学校和家庭——其中，家庭环境占据了相当大的比例，这一趋势因COVID-19疫情期间生活方式的改变而加剧 [9, 16]。尽管其健康风险已广为人知，但针对家庭环境中久坐行为的研究却十分有限，留下了显著的认知空白 [15]。因此，本研究旨在设计创新的、针对家庭场景的解决方案，以有效减少久坐行为。我们的核心研究问题是：如何设计交互技术来减少成年人在家庭中的久坐行为？为探究这一总体问题，我们聚焦于以下两个子问题：1) 人们在家中减少当前久坐行为面临哪些障碍？2) 人们希望通过技术解决家庭久坐行为时有哪些需求？

为回答研究问题，我们开展了一项为期七天的日记研究，聚焦5款现有改善久坐行为的应用，收集了56份调查问卷并对5名参与者进行访谈，以探究久坐行为。用户表现出改变久坐行为的动机不足，且对其长期危害或改善策略认知有限。研究发现强调需要非侵入式、情感驱动的解决方案，这些方案需提供清晰知识、低干扰的互动提醒及精准数据。针对这些需求，我们基于用户测试提出并优化设计方案，最终开发出SoleMate——一款搭载压力传感器的可穿戴拖鞋，配合具有非侵入式提醒、教育模块和数据可视化功能的桌面虚拟形象应用。SoleMate旨在通过

pressure sensors and provides real-time feedback via an empathetic avatar, blending seamlessly into home life. Overall, this work contributes to Sustainable Human-Computer Interaction (SHCI) both empirically by addressing the research gap in home-based sedentary behaviour through mixed-method insights and practically through the design that integrates non-invasive tracking and empathy-driven engagement to promote behaviour change.

2 RELATED WORKS

Existing interventions focus on improving motivation and knowledge to reduce sedentary behaviour effectively. Techniques such as gamification [11], goal-setting [18], and social rewards [17] have proven effective in enhancing motivation, particularly in workplaces, by encouraging individuals to break prolonged sitting and adopt active habits. Similarly, knowledge gaps, which hinder individuals from translating awareness into action, can be addressed through educational interventions like data visualisation [22], educational campaigns [21], and gamified education [11, 23], empowering individuals to make informed behavioural changes.

While these interventions have effectively enhanced physical activity by improving users' motivation and knowledge in workplace settings, translating these approaches to home environments requires careful consideration. Specifically, the significant differences in motivation sources and behaviour patterns between home and workplace settings make it challenging to apply workplace interventions to home environments. This difficulty arises because behaviours at home tend to be more flexible and diverse, often driven by intrinsic motivation due to the personal and individualised nature of the setting. These unique characteristics not only require intervention designs to be more personalised and adaptable but also highlight a lack of existing solutions tailored for home contexts. Furthermore, users' attitudes and cognition regarding sedentary behaviour in home settings remain largely unexplored, underscoring a critical research gap. Therefore, this design seeks to bridge the gap by exploring users' sedentary behaviour patterns and attitudes and developing user-centric solutions to encourage healthier habits in home settings.

3 USER RESEARCH

3.1 Method

To gain an understanding of how existing applications and devices reduce sedentary behaviour and their effectiveness, a semi-structured seven-day diary study[1] of 5 participants (4 female, 1 male; aged 21-23) was conducted. We selected five commercially available apps that range from wearable to phone-based apps. Participants were instructed to log the scenario and experience using the app or device and reflect on the designs and functions in a digital notebook. Besides, to explore the frequency of sedentary behaviour, barriers and expected functions to reduce sedentary behaviour in a larger population, a mixed-method questionnaire with 56 responses (34 female, 21 male, 1 preferred not to say; 30 age 18-25, 11 age 26-35, 11 age 36-45, 4 age 46-55) was utilised. To further investigate the survey findings, we followed up with a semi-structured interview with 5 participants (3 females, 2 males; aged 21-30). Interview scripts were analysed using a top-down reflexive thematic analysis with the COM-B model [5, 12].

3.2 Findings

We identified three key issues from the diary study: failure to monitor real-time sedentary data, monotonous and rigid reminders, and difficult suggested exercises. As a result, users ignore reminders and feel disrupted. The survey showed that sedentary behaviour is common but often overlooked. Among people aged 18 to 45, 67.3% met the criteria for sedentary behaviour, with about half unaware of it. Sedentary behaviour is low among participants aged 46-55 (25%), so they are not included in our target group. During prolonged sitting, most engage with digital devices for work or study (89.3%), social media (62.5%), and gaming (48.2%). This suggested digital interventions could be useful. Key barriers include discomfort, lack of motivation, time constraints, and concerns about productivity. Users expect real-time monitoring, personalized reminders, and task-based exercise guidance. Interviews revealed that users break sedentary behaviour mainly due to physical discomfort rather than health awareness, indicating a lack of understanding and motivation to prevent long-term harm. Wearables were seen as intrusive and inconvenient, leading to low adherence and eventual abandonment. Overall, people underestimate their sedentary time and overlook its long-term effects. Existing solutions fail to meet their needs, and overly difficult exercise advice further reduces motivation.

3.3 User Needs

Based on the user research above, we identified four main user needs (UN) for an effective sedentary behaviour intervention: namely 1) learning about long-term harms; 2) stopping prolonged sitting without disrupting current activity; 3) receiving engaging reminders; and 4) being able to view accurate sedentary data. These needs are repetitively confirmed in the diary study, questionnaire and interviews.

4 DESIGN PROCESS

4.1 Ideation

Based on the Need-Driven Design Model, we then conducted the Solution Exploration phase. We brainstormed various features for each need and conducted a 2 x 2 analysis (Figure 1) to evaluate the effectiveness and engagement. The brainstormed ideas were either inspired by suggestions from participants in user research, transformed from users' needs to detailed practical designs or intervention design suggestions from previous behaviour change studies [1].

[1]The Apps tested in the diary study are:
1) Apple Fitness (watch): https://apps.apple.com/us/app/fitness/id1208224953;
2) Time Out (laptop): https://apps.apple.com/us/app/time-out-break-reminders/id402592703?mt=12;
3) Sitting Alarmy: https://apps.apple.com/us/app/sitting-alarmy-reminder-alarm/id1611670179;
4) NeckGo: https://apps.apple.com/us/app/neckgo-relief-for-your-neck/id1660505668;
5) Stand Up!: https://apps.apple.com/us/app/stand-up-the-work-break-timer/id828244687

压力传感器无感监测长时间久坐，并通过共情化头像提供实时反馈，自然融入家庭生活。整体而言，本研究从实证层面通过混合方法洞察填补家庭久坐行为研究空白，从实践层面通过整合非侵入式追踪与共情驱动参与的设计促进行为改变，为可持续人机交互（SHCI）领域作出贡献。

2 相关工作

现有干预措施侧重于提升动机与知识以有效减少久坐行为。技术手段如游戏化 [11], 目标设定 [18], 及社交奖励 [17] 已被证明能有效增强动机，尤其在工作场所环境中，通过鼓励个体打破长时间久坐并养成积极习惯。同样，阻碍个体将意识转化为行动的知识鸿沟，可通过数据可视化 [22],教育模块 [21], 及游戏化教育 [11, 23],等教育干预手段解决，使个体有能力做出明智的行为改变。

尽管这些干预措施通过提升用户在工作场所环境中的动机与知识，有效促进了体育活动，但将这些方法迁移至家庭环境需审慎考量。具体而言，家庭与工作场所环境间动机来源和行为模式的显著差异，使得工作场所干预措施难以直接适用于家庭环境。这一困难源于家庭中的行为往往更具灵活性和多样性，通常由内在动机驱动，因其具有个人化与个性化的特性。这些独特特征不仅要求干预设计更具个性化和适应性，也突显了当前缺乏针对家庭场景的定制化解决方案。此外，用户对家庭环境中久坐行为的态度与认知仍待深入探索，这揭示了一个关键研究空白。因此，本设计旨在通过探究用户的久坐行为模式与态度，开发以用户为中心的解决方案，以促进家庭环境中更健康的习惯，从而弥合这一空白。

3 用户研究

3.1 方法

为了解现有应用与设备如何减少久坐行为及其有效性，我们开展了一项为期七天的半结构化日记研究1，涉及5名参与者（4女1男，年龄21-23岁）。我们选取了五款市售应用程序，涵盖从可穿戴设备到手机应用程序的不同类型。参与者需记录使用场景与体验，并在数字笔记本中反思设计与功能。此外，为探究久坐行为频率、障碍及预期功能以在更广泛人群中减少久坐行为，我们采用混合方法问卷收集了56份回复（34女21男，1人选择不透露性别；30人18-25岁，11人26-35岁，11人36-45岁，4人46-55岁）。为进一步验证调查结果，我们对5名参与者（3女2男，年龄21-30岁）进行了半结构化访谈。访谈文本采用基于COM-B模型 [5, 12]的自顶向下反思性主题分析法进行分析。

3.2 研究发现

我们从日记研究中发现了三个关键问题：无法监测实时久坐数据、单调且僵化的提醒以及困难的建议锻炼。这导致用户忽视提醒并感到被打扰。调查显示，久坐行为普遍但常被忽视。在18至45岁人群中，67.3%符合久坐行为标准，其中约半数人对此不自知。46-55岁参与者中久坐行为比例较低（25%），因此他们未被纳入我们的目标群体。在长时间久坐时，大多数人使用数字设备进行工作或学习（89.3%）、社交媒体（62.5%）和游戏（48.2%），这表明数字干预可能有效。主要障碍包括不适、缺乏动力、时间限制及对生产力的担忧。用户期望获得实时监控、个性化提醒和基于任务的锻炼指导。访谈揭示，用户中断久坐行为主要源于身体不适而非健康意识，表明其对预防长期危害缺乏理解和动机。可穿戴设备被认为具有侵入性且不便，导致低依从性并最终被弃用。总体而言，人们低估了自己的久坐时间并忽视了其长期影响。现有解决方案未能满足其需求，而过于困难的锻炼建议进一步削弱了动机。

3.3 用户需求

基于上述用户研究，我们总结出有效的久坐行为干预需满足四大用户需求（UN）：1）了解长期危害；2）在不打断当前活动的情况下停止长时间久坐；3）接收互动提醒；4）能查看准确的久坐数据。这些需求在日记研究、问卷调查和访谈中得到了反复验证。

4 设计流程

4.1 构思阶段

基于需求驱动设计模型，我们随后开展了解决方案探索阶段。我们针对每项需求进行了功能头脑风暴，并通过2 x 2分析（图1）评估方案的有效性与参与度。这些头脑风暴的想法或源自用户研究中参与者的建议，或将用户需求转化为具体实践设计，亦或借鉴了先前行为改变研究[1]中的干预设计方案。

1日记研究中测试的应用包括：1) Apple Fitness（手表版）：https://apps.apple.com/us/app/fitness/id1208224953；2) Time Out（笔记本版）：https://apps.apple.com/us/app/time-out-break-reminders/ id402592703?mt=12; 3) Sitting Alarmy：https://apps.apple.com/us/app/sitting-alarmy-reminder-alarm/ id1611670179; 4) NeckGo：https://apps.apple.com/us/app/neckgo-relief-for-your-neck/ id1660505668；5) Stand Up!：https://apps.apple.com/us/app/stand-up-the-work-break-timer/ id828244687

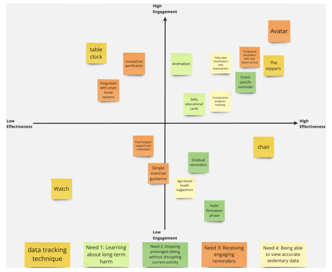

Figure 1: Results of the 2 x 2 matrix analysis on effectiveness and engagement (created in Miro.com)

4.2 First Prototype

We designed an application aimed at reducing sedentary behaviour, which features slippers equipped with sensors to detect real-time sitting activity (Figure 2).

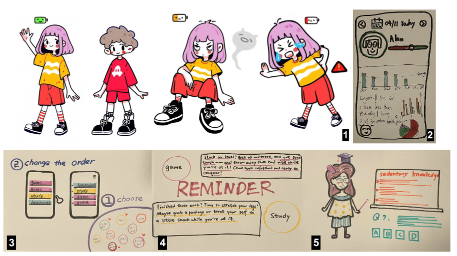

Figure 2: Sketches of the first prototype: (1) Avatars in different statuses. (2) Data visualisation page. (3) Self-set schedule page. (4) Contextual reminders. (5) Education with avatar page.

4.2.1 Slipper. Slippers are one of the most frequently used items in home life and closely align with user behaviour, enabling natural sedentary behaviour monitoring while avoiding the burden of wearing additional devices and ensuring continuous and accurate data collection. Our slippers contain Arduino pressure sensors to detect body postures. When people sit down, the pattern of pressure on the slipper is different from other postures, therefore we can calculate the sitting time using the slipper. It addresses users' needs to be able to view accurate sedentary data (UN4).

4.2.2 Contextual Reminders and Avatar. Based on our user research findings, we developed a context-aware reminder system with a customisable avatar that serves as an implicit reminder that was designed to be unobtrusive while still effective. This solution aimed to satisfy UN2 and UN3. Such a reminder aims to boost the user's confidence in successfully completing the task by offering clear and straightforward guidelines tied to existing activities. By making the reminder more acceptable and actionable, this approach reduces the challenge of improving sedentary behaviour, thereby increasing the likelihood of users taking action [2]. Meanwhile, the virtual avatar we designed will gradually display signs of pain, fatigue, or low energy as the user's sedentary time increases. Since the avatar remains visible on the screen, its state-based changes serve as subtle reminders without being perceived as intrusive. Empirical findings [23] and theoretical foundations [4] support the ability of customisable, interactive avatars to motivate positive action by enhancing bodily awareness and empathy. These feelings can prompt users to reflect on sedentary behaviour and health risks, strengthening their intention to act [8]. Additionally, when users stand and move, the avatar instantly returns to a healthy state, offering positive reinforcement and promoting long-term adherence to reminders.

4.2.3 Education. To enable users to learn about the long-term harm (UN1) of sedentary behaviour through interactions, we designed an interactive education section with a daily multiple-choice question. This section is here to ensure that users understand how prolonged sitting could be harmful and learn how to reduce the harm, thus raising their awareness of reducing sedentary behaviour. In this part, users answer one multiple-choice question every day. The avatar reacts happily or sadly to correct or wrong answers accordingly.

4.2.4 Data Visualisation. To help users maintain long-term engagement and fulfil UN4, we provide clear graphs and actionable feedback. This visualisation helps users become aware of their current behaviour patterns through real-time feedback, such as a comparison indicating "2 hours less sitting than yesterday," reinforcing their self-efficacy and motivation to reduce sedentary behaviour [2]. Additionally, it offers long-term trend analysis, fostering a sense of achievement and encouraging users to sustain healthier habits. Through clear and motivating visual feedback, this data visualization could enhance awareness and accomplishment, driving behaviour change and supporting sustained reductions in sedentary activity.

4.3 User Testing

Given the limited research on the effectiveness of using interactive avatars for education and situation-based reminders in home settings, we conducted a controlled experiment with a Wizard-of-Oz design of 11 participants (4 female, 6 male, 1 preferred not to say; 10 aged 18-25, 1 age 26-35) was conducted. A follow-up interview with 3 participants (2 female, 1 male; age 21-25) was conducted. Participants were recruited using convenience sampling. The majority of our participants reported moderate to severe sedentary behaviour at home.

Participants rated the avatar and interactive questions as somewhat effective and engaging and liked the presentation. However, some participants suggested providing more detailed information about the knowledge presented after answering questions and expressed a desire for greater interaction with the avatar. We also found that even when presented with task-related reminders, participants still focused on current tasks and were not motivated to stand up. Participants revealed that text-based reminders are not motivational, whereas reminding them of the harm of sedentary behaviour and visually salient and attractive changes are useful. The evaluation study and feedback guided the development of the high-fidelity prototype (Figure 3).

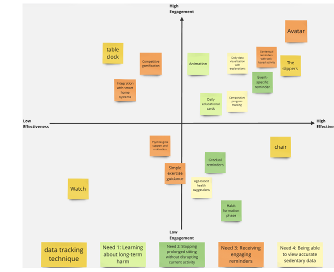

图1：关于有效性与参与度的2×2矩阵分析结果（制作于Miro.com）

4.2 第一版原型

我们设计了一款旨在减少久坐行为的应用，其特点是配备传感器的拖鞋可检测实时坐姿活动（图2）。

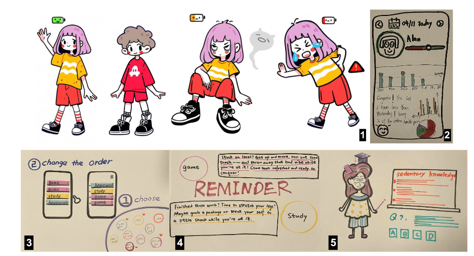

图2：第一版原型草图：(1)不同状态的头像。(2)数据可视化页面。(3)自定义日程页面。(4)情境提醒。(5)带头像的教育模块页面。

4.2.1 拖鞋。拖鞋是家庭生活中最常使用的物品之一，与用户行为高度契合，能自然监测久坐行为，避免额外穿戴设备的负担，并确保持续准确的数据收集。我们的拖鞋内置Arduino压力传感器以检测身体姿势。当人坐下时，拖鞋上的压力分布与其他姿势不同，因此可通过拖鞋计算坐姿时间。该设计满足了用户查看精准久坐数据的需求（UN4）。

4.2.2 情境提醒与虚拟形象。基于用户调研结果，我们开发了一套情境感知提醒系统，配备可定制虚拟形象作为隐性提醒载体，设计上既保持低调又确保有效性。该方案旨在满足UN2和UN3需求。此类提醒通过绑定现有活动提供清晰直观的指引，增强用户完成任务的自信心。通过提升提醒的可接受性与可操作性，该方法降低了改善久坐行为的难度，从而增加用户采取行动的可能性 [2]。同时，我们设计的虚拟形象会随用户久坐时间延长逐渐显现疼痛、疲劳或低能量状态。由于头像始终显示在屏幕上，其状态变化能持续发挥非侵入式的微妙提醒作用。实证研究 [23] 与理论基础 [4] 表明，可定制的交互式虚拟形象能通过增强身体意识和同理心来激励积极行动。这些情感因素可促使用户反思久坐行为及健康风险，强化其行动意愿 [8]。此外，当用户起身活动时，虚拟形象会立即恢复健康状态，提供正向强化并促进对提醒的长期坚持。

4.2.3 教育模块。为了让用户通过互动了解久坐行为的长期危害（UN1），我们设计了一个包含每日选择题的互动教育模块。该模块旨在确保用户理解长时间久坐可能带来的危害，并学习如何减少这些危害，从而提高他们减少久坐行为的意识。在此部分，用户每天需回答一个多项选择题。头像会根据答案正确与否作出开心或难过的反应。

4.2.4 数据可视化。为帮助用户保持长期参与度并实现UN4目标，我们提供了清晰的图表和可操作的反馈。该可视化功能通过实时反馈（例如显示“比昨天少坐2小时”的比较数据）让用户意识到当前的行为模式，从而增强其减少久坐行为的自我效能感和动机 [2]。此外，它还提供长期趋势分析，培养用户的成就感，鼓励其维持更健康的习惯。通过清晰且激励性的视觉反馈，这种数据可视化能够提升意识与成就感，推动行为改变，并支持持续减少久坐活动。

4.3 用户测试

鉴于目前关于在家庭环境中使用交互式虚拟形象进行教育模块和情境提醒的有效性研究有限，我们采用Wizard-of-Oz设计对11名参与者（4名女性，6名男性，1名不愿透露；10名年龄18-25岁，1名26-35岁）进行了受控实验。随后对其中3名参与者（2名女性，1名男性；年龄21-25岁）进行了跟踪访谈。参与者通过便利抽样方式招募。大多数参与者报告称在家庭环境中存在中度至重度久坐行为。

参与者评价头像和交互式问题具有一定效果和吸引力，并喜欢其呈现方式。然而，部分参与者建议在回答问题后提供更多关于所展示知识的详细信息，并表达了与头像进行更多互动的愿望。我们还发现，即使收到与任务相关的提醒，参与者仍专注于当前任务，缺乏起身的动机。参与者透露，基于文字的提醒缺乏激励性，而提醒久坐行为的危害以及视觉上突出且吸引人的变化则更为有效。评估研究和反馈指导了高保真原型（图3）的开发。

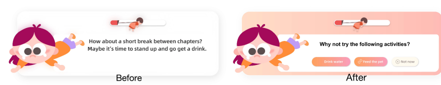

Figure 3: Iteration on the prototype of avatar reminders based on the first user testing (created in Figma)

4.4 Second Prototype

Based on feedback from the first usability test, we deleted situation-based reminders as participants found them ineffective and removed the schedule setting feature. Instead, we highlighted the harm of sedentary behaviour by using icons to raise users' motivation to reduce sedentary behaviour. Some short exercise suggestions would pop up when users' sedentary behaviour was detected. Moreover, we add information sources and practical strategies to reduce sedentary behaviour after daily interactive questions to enhance users' understanding of knowledge.

4.4.1 Heuristic Evaluation. A high-fidelity wireframe prototype was designed and evaluated using Nielsen's 10 usability heuristics. Our prototype has high user control freedom and consistency, but it lacks help and documentation. Therefore, we added introductory pages and a help centre to assist new users in using our app. We also redesigned some interface layouts to improve the clarity of user experience (Figure 4).

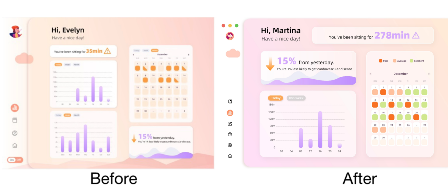

Figure 4: Iteration on the prototype of the data visualisation page (created in Figma)

4.5 Final Design

4.5.1 Slipper. Our slipper detects users' body positions using Arduino pressure sensors. Sensors are built inside the slipper so that users would not feel uncomfortable wearing our slipper. It can be paired with the device's IP address so that the application can distinguish the inactivity of the slipper between sleeping and leaving home.

4.5.2 App. The final prototype contains an onboarding page, customisation page, home page, helping centre, education or 'question for the day' page, data visualisation page and a desktop interactive avatar (Figure 5).

The onboarding pages introduce key features of our application. New users are then led to the customisation page, which allows them to customise the avatar's appearance and name. Users can update the avatar at any time. The created avatar will appear as the profile picture and floating desktop decoration when users minimise the app. On the home page, users are presented with the avatar, the total amount, a bar graph of today's sitting time, and a comparison between today's and yesterday's sitting time. On the

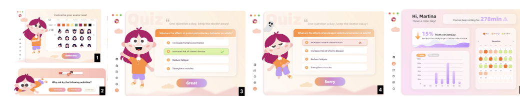

Figure 5: Interfaces of SoleMate. (1) Avatar customisation page. (2) Avatar desktop reminder. (3) Education page when answered correctly. (4) Education page when answered incorrectly. (5) Data visualisation page (created in Figma)

helping page, a simple explanation and guidance for each page are listed to facilitate users' interaction with SoleMate.

On the education page, a daily quiz question and the avatar are presented in the form of multiple-choice. After answering the response, the correct answer, detailed information about the answer and information source pop up. The avatar also shows corresponding facial expressions according to whether users answered correctly to deepen their memories. The daily questions are about the long-term harm of sedentary behaviour and everyday examples of how to reduce sedentary behaviour. The notebook collects previous questions and explanations for users to review.

The data visualisation page displays graphs of sitting time for the day, week, and month. The bar chart shows how many minutes users sit every 4 hours in a day. The aggregated sedentary time is also summarised. Weekly sitting hours and a comparison between today's and yesterday's sitting times are displayed." There is also a coloured calendar highlighting sedentary behaviour. Each day is either green (0-4 hours), yellow (4-8 hours) or red (more than 8 hours) based on the sitting time of that day. When users select a specific day on the calendar, a bar chart of that day and the total time spent sitting will appear.

Finally, there is a desktop avatar with an energy bar to remind users to stand up. The avatar becomes less energetic when users remain sitting, and the energy bar changes from green (0-15 minutes) to yellow (15-30 minutes) to red (more than 30 minutes). When the sitting time reaches the sedentary criteria, an icon highlighting the painful body parts pops up to remind people of the harm of prolonged sitting. Two simple guidance also pops up to suggest users move. When users stop sitting after seeing reminders, the avatar becomes energetic again as a reward.

5 DISCUSSION

Few existing research and products for reducing sedentary behaviour effectively target sedentary behaviour at home. Therefore, our work designed a prototype SoleMate, which intends to reduce sedentary behaviour at home by communicating knowledge, reflecting on the history of sitting time, and highlighting the harms of sedentary behaviour through avatars. These features aim to allow users to not only reduce current prolonged sitting but also enhance the motivation to keep a healthier lifestyle at home.

The limitations of this study include the small sample size in the usability tests. Since reasons and scenarios for prolonged sitting at home can be different among users, a larger sample with users in different employment statuses or age groups will be helpful in evaluating our design. This study focused on testing specific functions in isolation rather than evaluating the overall user experience of the comprehensive application. It is also conducted in a controlled

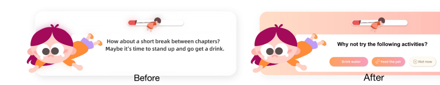

图3: 基于首次用户测试的头像提醒功能原型迭代（使用Figma制作）

4.4 第二版原型

根据首次可用性测试的反馈，我们删除了基于情境的提醒（因参与者认为其无效），并移除了日程设置功能。取而代之的是，我们通过图标突出久坐行为的危害，以提升用户减少久坐行为的动机。当检测到用户久坐行为时，会弹出简短的运动建议。此外，我们在每日互动问题后添加了信息来源和减少久坐行为的实用策略，以增强用户对知识的理解。

4.4.1 启发式评估。我们设计了高保真线框图原型，并采用尼尔森十大可用性原则进行评估。该原型在用户控制自由度与一致性方面表现优异，但缺少帮助与文档支持。为此我们新增了介绍页面和帮助中心以引导新用户使用应用，同时重新设计了部分界面布局以提升用户体验的清晰度（图4）。

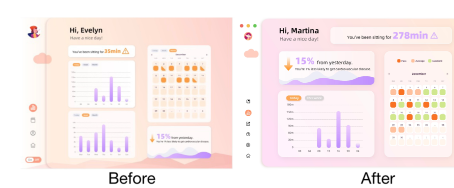

图4: 数据可视化页面原型迭代（使用Figma制作）

4.5 最终设计

4.5.1 拖鞋。我们的拖鞋通过Arduino压力传感器检测用户的身体姿态。传感器内置在拖鞋内部，确保用户穿着时不会感到不适。它可通过设备IP地址进行配对，使应用能区分拖鞋处于睡眠状态还是用户离家时的静止状态。

4.5.2 应用。最终原型包含引导页面、自定义页面、主页、帮助中心、教育模块（即"每日问题"页面）、数据可视化页面以及桌面互动头像（图5）。

引导页面介绍了我们应用的核心功能。新用户随后会被引导至自定义页面，在此可个性化设置头像外观与名称。用户可随时更新头像。创建的头像将作为个人资料图片显示，并在用户最小化应用时以浮动桌面装饰形式呈现。主页上展示着用户头像、总量统计、今日坐姿时间的柱状图，以及今日与昨日坐姿时间的比较数据。

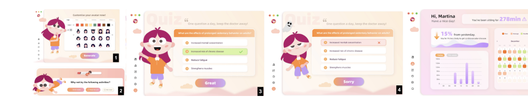

图5：SoleMate界面。(1)头像自定义页面。(2)桌面头像提醒。(3)回答正确时的教育页面。(4)回答错误时的教育页面。(5)数据可视化页面（使用Figma创建）

帮助页面列出了每项功能的简明解释与操作指引，以便用户更顺畅地与SoleMate进行交互。

在教育页面中，每日测验问题与头像以多项选择形式呈现。回答后，系统会弹出正确答案、答案详细信息及信息来源。头像还会根据用户回答正误显示相应面部表情，以加深记忆。每日问题涉及久坐行为的长期危害及减少久坐的日常示例。笔记本功能会收集历史问题与解析供用户复习。

数据可视化页面展示了当天、当周及当月的坐姿时间图表。条形图显示用户每日每4小时久坐的分钟数，同时汇总了累计久坐时间。页面还呈现每周坐姿小时数以及今日与昨日坐姿时间的比较。此外，彩色日历会突显久坐行为——根据每日坐姿时长，日期会标记为绿色（0-4小时）、黄色（4-8小时）或红色（超过8小时）。当用户点击日历中特定日期时，将显示该日的条形图及总坐姿时长。

最后，桌面头像配有能量条以提醒用户起身活动。当用户持续久坐时，头像会逐渐失去活力，能量条颜色由绿色（0-15分钟）变为黄色（15-30分钟），最终转为红色（超过30分钟）。当坐姿时间达到久坐标准时，系统会弹出图标高亮疼痛的身体部位，警示长时间久坐的危害，并伴随两条简单指导建议用户活动。若用户看到提醒后停止久坐，头像将恢复活力作为奖励。

5 讨论

现有针对减少久坐行为的研究和产品中，鲜少能有效针对家庭环境中的久坐行为。因此，我们设计了一款原型产品SoleMate，旨在通过知识传播、坐姿时间历史回顾以及通过头像突显久坐行为危害的方式，减少家庭中的久坐行为。这些功能不仅帮助用户减少当前长时间久坐，还旨在增强他们在家庭中保持更健康生活方式的动机。

本研究的局限性包括可用性测试中的样本量较小。由于用户在家中长时间久坐的原因和场景可能各不相同，采用包含不同职业状态或年龄组的更大样本量将有助于评估我们的设计。本研究侧重于孤立测试特定功能，而非评估该综合应用的整体用户体验。此外，研究是在受控的

setting, and participants' performance may deviate from their daily performance. Future studies can assess the effectiveness of daily use using a diary study with participants from different daily routines. Specifically, future studies can focus on whether reminders are disruptive and whether users follow reminders to break their sedentary behaviour.

Our design aims to reduce sedentary behaviour at home among people aged 18 to 45, as the sedentary lifestyle is physically and emotionally harmful yet widespread. SoleMate uses a non-invasive slipper to monitor sedentary behaviour and fits in home settings. It also communicates knowledge and reminds users through an empathy-eliciting avatar, which can lead to not only behavioural change but also an increase in motivation. By using SoleMate continuously, users can gradually form a non-sedentary lifestyle and exercise habits, aligning with promoting a healthy lifestyle in SDG3. Combining non-invasive design and emotionally resonant feedback offers a unique contribution to HCI. By balancing usability, emotional engagement, and unobtrusiveness, SoleMate bridges the gap in interventions to reduce sedentary behaviour at home. It demonstrates how emotional cues can effectively drive behaviour and motivation change, inspiring new directions for empathy-driven design in promoting healthier lifestyles, as suggested in SDG3. In future work, we aim to enhance the project's credibility and validity by incorporating broader stakeholder involvement, including input from health professionals and behaviour change experts.

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环境中进行的，参与者的表现可能与其日常表现存在偏差。未来研究可通过日记研究，选取具有不同日常作息的参与者来评估日常使用效果。具体而言，未来研究可重点关注提醒是否具有干扰性，以及用户是否会遵循提醒来中断其久坐行为。

我们的设计旨在减少18至45岁人群在家庭环境中的久坐行为，因为久坐生活方式对身心有害却普遍存在。SoleMate采用非侵入式拖鞋监测久坐行为，完美融入家庭场景。它通过一个引发共情的虚拟形象传递知识并提醒用户，不仅能促进行为改变，还能增强动机。持续使用SoleMate可帮助用户逐步形成非久坐生活方式和锻炼习惯，契合可持续发展目标3中倡导的健康生活方式。结合非侵入式设计与情感共鸣反馈，该项目为人机交互领域提供了独特贡献。通过平衡可用性、情感互动与无干扰性，SoleMate填补了家庭久坐行为干预措施的空白。它证明了情感线索如何有效驱动行为与动机改变，为共情驱动设计促进更健康生活方式开辟了新方向（如可持续发展目标3所述）。在后续工作中，我们将通过纳入更广泛利益相关者（包括健康专业人士和行为改变专家）的参与，提升项目的可信度与有效性。

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