Hochschule Neu-Ulm
University of Applied Sciences

Bachelorarbeit

im Bachelorstudiengang

Game-Produktion und Management

an der Hochschule für angewandte Wissenschaften Neu-Ulm

Smart City Applications for Health:
Counteracting a lack of physical activity

Erstkorrektor: Prof. Dr. Heiko Gewald

Zweitkorrektor: Prof. Dr. Heinz-Theo Wagner

Verfasser: Lukas Fuchs (Matrikel-Nr.: 273126)

Thema erhalten: 26.07.2023

Arbeit abgeliefert: 27.11.2023

Abstract

Background

Health in urban areas is a significant concern, with health interventions showing effectiveness in addressing this issue. This study centres on the Living Cities application, aiming to evaluate its overall effectiveness and user acceptance by leveraging the UTAUT2 and HBM models. The potential impact of such an assessment should not be overlooked.

Purpose

This study examines the effectiveness and acceptance of the Living Cities application, exploring how technology, urban living, and health intersect. Utilizing the UTAUT2 and HBM models, the study delves into user-centric design and functionality dimensions to unravel critical in-sights.

Research Questions

What is the current state of information regarding the impact of smart city applications on promoting physical activity and enhancing health outcomes?

To what extent do users' perceived health benefits and barriers influence their willingness to use smart city applications regularly?

How can the Living Cities application be optimized to encourage increased physical activity in urban settings?

Methodology

Qualitative research, comprising of interviews with a sample of twelve participants, was carried out to evaluate user perceptions and engagement with the Living Cities application. The study utilized the UTAUT2 and HBM models to provide an all-inclusive comprehension of the application's efficacy.

Results

Incorporating gamification elements in user engagement, especially through the implementation of a reward system, is crucial. However, the study highlights that technical difficulties and expected effort could be potential obstacles. Furthermore, the study concludes that enjoyment and emotional motivation significantly impact user interactions. Participants aim for an application enhancement that mirrors a user-driven approach by desiring an extended coupon system, a diverse range of challenges, more social challenges, and enhanced transparency in tracking procedures.

Discussion

The research enhances the ongoing discourse surrounding technology acceptance models by highlighting the critical nature of hedonic motivation within the UTAUT framework. It presents a challenge to prevailing assumptions concerning the direct health effects of mobile applications, underscoring the necessity for personalised interventions. Moreover, the research acknowledges the favourable impact of

gamification components, particularly the reward schemes, on user involvement. This offers valuable insights for professionals and academics in the domain.

Conclusion

The research concludes that health applications in smart city environments need user-centric design, attention to technical challenges, and optimized gamification elements to be effective. Although the Living Cities application holds promise, it requires refinement to have a sustained impact on users' physical activity and well-being.

Keywords: Health Applications, Gamification, Physical Activity, Smart Cities, User Experience

Structure

List of Figures

List of Tables

List of Abbreviations

UTAUT	Unified Theory of Acceptance and Use of Technology
PE	Performance Expectancy
EE	Effort Expectancy
SI	Social influence
FC	Facilitating Conditions
BI	Behavioural Intention
AU	Actual Use
HBM	Health Belief Model
mHealth	mobile Health
IoT	Internet of Things
ICT	information communications technology
AI	Artificial Intelligence
ML	Machine Learning
AR	Augmented Reality
VR	Virtual Reality
TDF	Theoretical Domains Framework
MET	Metabolic Equivalent of Task
BMI	Body Mass Index
FBM	Fogg Behaviour Model
SCT	social cognitive theory
ANOVA	Analysis of Variance

1 Introduction

Urban environments, despite being hubs of activity, are facing a pressing issue of physical inactivity. According to (Eremia et al. 2017), this trend of being sedentary in urban areas is strongly connected to several health problems, including obesity, diabetes, and cardiovascular diseases. The rapidly growing challenge of physical inactivity in urban areas calls for innovative solutions, and emerging technologies present a promising avenue to explore.

Smart city applications have become potent influencers in promoting physical activity and cultivating healthier lifestyles. By exploiting the dependency on smartphones, these applications bridge the technological gap to urban health challenges and offer a prospect to reform the residents' health behaviours. The gamification strategies, as encouraged by (Deterding et al. 2011), integrated within smart city applications can provide a captivating and gratifying experience while pursuing an active lifestyle.

Smart city applications are effective tools for tackling key urban health issues. (Sucasas et al. 2016) highlight their potential for reducing sedentary behaviour and associated health risks. This focus on promoting healthier urban lifestyles goes beyond being just a technological trend and is a strategic response to the evolving health landscape of modern cities.

Research Questions:

This thesis aims to navigate the intersection of technology, urban living, and health by examining how smart city applications can genuinely encourage increased physical activity in urban settings. In pursuit of this goal, the exploration of user-centric design and functionalities drives the critical dimensions that will be unravelled.

What is the current state of information regarding the impact of applications on promoting physical activity and enhancing health outcomes? The present thesis analyses the existing body of knowledge and assesses the effectiveness and implications of such applications.

Specifically, to what extent do users' perceived health benefits and barriers of health applications influence their willingness to use them regularly? This query investigates the objective and practical determinants affecting user involvement with smart city applications.

How can the smart city application be optimized to encourage increased physical activity in urban settings?

The thesis aims to provide a refined comprehension of the continuously changing aspects of smart city applications, their influence on physical activity, and their wider implications for urban health and well-being.

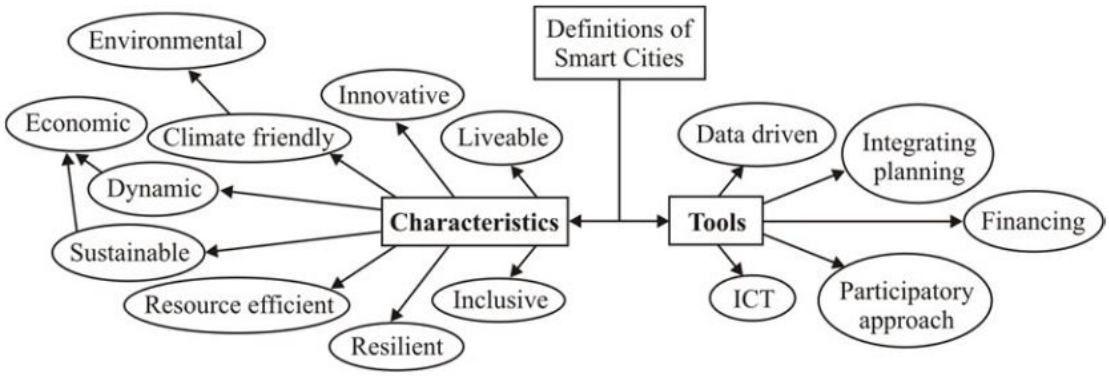
2 Theoretical Framework / Literature Review

2.1 Smart Cities

2.1.1 Definition

As urbanization continues to drive unprecedented population growth within cities, the imperative for intelligent and efficient urban environments becomes increasingly pronounced (Eremia et al. 2017). The surge in urban populations brings forth a host of challenges, including overpopulation, escalating energy consumption, intricate resource management, and the pressing need for environmental preservation (Eremia et al. 2017).

The conceptualization of a “smart city” revolves around the strategic application of information and communication technology (ICT) to elevate the quality of life, enhance functionality, and promote sustainability in urban regions (Eremia et al. 2017). At its core, the smart city paradigm aims to harness ICT to formulate intelligent, analytics-based solutions that not only improve the living standards of city dwellers but also optimize various facets associated with urban living (Eremia et al. 2017).



1 Characteristics and tools used to define the Smart City (Eremia et al. 2017)

Figure 1 illustrates the primary features and instruments commonly associated with smart cities. These instruments typically encompass cutting-edge technologies, robust data analysis, and the pervasive integration of Internet of Things (IoT) devices (Eremia et al. 2017). The amalgamation of these components is pivotal for the realization of intelligent urban infrastructure. (Eremia et al. 2017)

The incorporation of these technological advancements empowers smart cities to confront and overcome urban challenges effectively. By enhancing efficiency, responsiveness, and sustainability, smart cities leverage ICT and data-driven approaches to stimulate innovation and progress within the contemporary urban landscape of the 21st century. (Eremia et al. 2017)

The challenges arising from the growth of urban populations are complex, and smart cities emerge as a strategic response to address these challenges. In addition to those mentioned, smart cities also face issues surrounding traffic congestion, waste management, and the equal distribution of resources (Eremia et al. 2017). The use of ICT plays a crucial role in transforming these challenges into opportunities for optimizing urban living. (Eremia et al. 2017)

Moreover, the use of IoT devices, as demonstrated by the interconnectivity of urban infrastructure, allows for real-time gathering and analysis of data (Eremia et al. 2017). This dynamic, data-driven approach empowers smart cities to make informed decisions, optimize resource allocation, and promptly address the changing needs of their residents. (Eremia et al. 2017)

As smart cities' definition evolves, it is vital to consider socio-economic implications, governance structures, and citizen engagement strategies. These factors contribute to the holistic development of intelligent urban spaces. The theoretical foundation of smart cities spans beyond technological components, incorporating the broader vision of creating inclusive, sustainable, and resilient urban ecosystems.

2.2 Smart Cities and Health Promotion

The convergence of smart cities and health promotion is a constantly developing and dynamic field (Gabriele et al. 2011). It is characterized by rapid advances and transformative potential (Gabriele et al. 2011). There is a promising opportunity to improve public health by using mobile applications and technology to encourage physical activity and healthy lifestyles in urban environments (Gabriele et al. 2011). While the field is still relatively new, e-Health applications exhibit the potential to have a considerable impact on public health outcomes by encouraging exercise and promoting positive behaviours in cities (Gabriele et al. 2011).

According to studies, the incorporation of health-related smart city applications shows promise in motivating individuals to adopt and sustain regular physical exercise routines (Fanning et al. 2012). Research indicates a positive association between using health-related applications and heightened physical activity (Fanning et al. 2012). The variety of available applications demonstrates their efficacy in increasing step counts and fostering habits among users.

Smartphone applications have become essential instruments in the field of health promotion, specifically in motivating compliance with physical activity guidelines. These applications proffer an economical and straightforward means of engaging with health information technology, yielding a significant international user audience, with nearly 63% of adults possessing smartphones in 2017 (Romeo et al. 2019). The prevalence of smartphones enables the creation of interactive applications that exploit real-time data using functions like internet connectivity, GPS, and accelerometers (Riley et al. 2011). The effortless amalgamation and extensive adoption of mobile phones make a significant contribution to the efficacy of programs that seek to encourage physical exercise (Romeo et al. 2019).

The present research highlights the vast potential of healthcare smart city applications in tackling the rising problem of physical inactivity in urban regions. They also highlight the vast potential of healthcare smart city applications in tackling the rising problem of physical inactivity in urban regions. These applications, utilizing the features of modern technology, can transform individual behaviours, encouraging healthier livelihoods in metropolitan settings (Romeo et al. 2019). Nevertheless, it is essential to acknowledge that the sector is still developing, and more extensive research is necessary to thoroughly apprehend the repercussion of these applications and ascertain the most advantageous methods for their construction and efficient execution (Romeo et al. 2019).

As smart city initiatives continue to grow, the convergence of technology and health promotion is crucial for fostering well-being in urban populations. Smart city applications have the potential to address a range of health challenges, from mental health support to chronic disease management, in addition to promoting physical activity. The advancing smart cities terrain presents an opportunity for innovative schemes stretching beyond standard healthcare limitations, to establish a comprehensive blueprint for urban welfare.

2.3 Health Applications

(Mosa et al. 2012) seminal study aimed to classify healthcare technologies based on smartphone functionalities, providing a nuanced comprehension of the various applications of smartphones in healthcare.

The findings not only highlight the increasing use of medical applications by healthcare professionals and patients, but also underscore the developing significance of smartphones in evidence-based medicine, clinical communication, patient education, disease self-management, and remote patient monitoring.

The development of patient engagement in health management has stimulated the use of mobile applications for delivering behavioural health interventions (Milne-Ives et al. 2020). This transition towards utilising smartphone applications for behavioural health highlights the constantly evolving nature of technology in promoting the overall well-being of individuals.

(Romeo et al. 2019) provided a significant statistic showcasing that globally, there are more activated mobile phones than there are citizens. The high prevalence of smartphones is significant and implies the far-reaching impact of mobile health interventions at a global level.

The worldwide prevalence of smartphones is on the rise, with forecasts predicting a continuous growth. (J. Degenhard 2023), research estimates that the user base for smartphones will climb to 5.1 billion by 2028, highlighting the persistent significance and application of smartphones in diverse domains of daily life, such as healthcare.

When investigating the practicality of health applications, (Rabin and Bock 2011) carried out a study concentrating on how users participate with physical activity applications. The results highlighted that users favour applications that are adaptable, track physical activity automatically, monitor goal progress, have music features, well-documented interfaces and features are easily understood. These findings offer a subtle perception of user expectations and can help shape the design and expansion of forthcoming health applications.

2.4 Gamification in Health Behaviour Change

Gamification involves strategically integrating game-like rewards and incentives with desired behaviours, aiming to enhance motivation and foster long-term habits (Deterding et al. 2011). In the realm of health behaviour change, gamification has received substantial attention and established itself as a significant theme in the health application industry (Deterding et al. 2011). Despite its widespread use, there is still a lack of comprehensive research examining the impact of gamification on health behaviour constructs. Furthermore, there is limited understanding of the extent to which gamification is integrated into health applications (Lister et al. 2014).

Currently, there has been a significant increase in the integration of gamification into health and fitness applications (Lister et al. 2014). The proliferation of applications on platforms such as the Apple Application Store that incorporate gamification elements is indicative of a trend (Lister et al. 2014). Nevertheless, this rise prompts enquiries regarding the successful incorporation of behavioural theories into gamification strategies and its effects on the efficacy of interventions aimed at altering behaviours (Lister et al. 2014). The application ecosystem offers a promising platform for disseminating health behaviour change interventions, marking a burgeoning field with considerable potential for exploration (Lister et al. 2014).

Amidst the changing landscape of health behaviour change interventions, a thorough examination of gamification's capacity to facilitate behavioural transformations is imperative (Lister et al. 2014). The use of gamification elements to encourage health-promoting behaviours shows potential, but the complex relationship between gamification, health applications, and behavioural modification requires further exploration (Lister et al. 2014). Conducting a comprehensive review and evaluation of the various

dimensions of gamification in promoting health behaviour change is essential in order to reveal nuanced impacts and inform future strategies for effective intervention design (Lister et al. 2014).

In conclusion, the increasing use of gamification in health and fitness applications highlights its noteworthy role in shaping interventions that modify health behaviours. However, an in-depth investigation into the relationship linking gamification strategies, health applications, and behavioural changes is needed. This study strives to bridge this gap in knowledge by exploring the various dimensions of gamification's influence on health behaviour constructs and its potential for cultivating sustainable behavioural change.

2.5 Research Gap

A thorough assessment of the effectiveness of a smart city application that promises to encourage physical activity and enhance health outcomes is lacking (Rocha et al. 2019). Numerous studies have concentrated on particular applications or application features, but more systematic research is required to assess the overall effects of a smart city application on outcomes related to physical activity and health (Rocha et al. 2019). There is a lack of knowledge regarding the precise attributes of smart city applications that work best to encourage physical activity and enhance health outcomes (Rocha et al. 2019).

More research is needed to determine the short-term usefulness and impact of smartphone applications for physical activity promotion. While these applications are widely available, there is a research vacuum in that there have been few studies that look at the long-term engagement, adherence, and behaviour change outcomes connected with them. More rigorous studies, particularly longitudinal studies, are also required to better understand how smartphone applications might successfully drive physical activity over time and lead to improved health outcomes (Flores Mateo et al. 2015).

2.6 Current state of research

2.6.1 Impact of (Smart City) Applications on Physical Activity Promotion

The potential of smart city applications in promoting physical activity has been widely acknowledged in the literature (Ek et al. 2018). Particularly, gamification and reward systems have emerged as promising strategies for encouraging users to participate in various physical activities (Lincoln C. Wood and Torsten Reiners). These characteristics aim to enhance user motivation and engagement, contributing to a more active and health-conscious community within the smart city context.

2.6.2 Relationship Between Smart City Applications and Health Outcomes Improvement

While the connection between smart city applications and health outcome improvements is an evolving field, a study by (Milne-Ives et al. 2020) suggests a positive correlation. Nonetheless, it is essential to acknowledge the current gaps in knowledge, as noted by (Litman et al. 2015). They observed that although more than 1000 exercise applications for mobile devices exist, their actual impact on exercise levels and health outcomes remains unclear.

2.6.2.1 Barriers and Motivators for Health Application Adoption

(Ahmad et al. 2022) investigated the hindrances and incentives to the uptake of health applications among older adults. The study identified several barriers, including insufficient awareness, technological competencies, perceived capacity, schedules, lack of expert participation, and anxieties related to security and confidentiality. On the other hand, motivators included characteristics from reliable sources,

legitimate qualifications, consistent enhancements in design interfaces, and customised features tailored to the precise requirements of elderly individuals.

2.6.2.2 Long-term Impact of Exercise Applications on Health

(Litman et al. 2015) carried out a comprehensive study involving 726 participants with different backgrounds related to exercise application usage. The research assessed participants who had not previously utilized exercise applications, those who had used and ceased, and those presently utilizing exercise applications.

The research revealed that almost three-quarters of current application users reported being more active compared to non-users and past users, which is a significant finding.

Current users had a greater total expenditure of leisure time (measured in metabolic equivalents of the task, MET) in comparison to those who had not used or stopped using fitness applications.

The study indicated that exercise application users were more likely to engage in physical activity during their leisure time, fulfilling the intended function of these applications. Furthermore, the data suggested that exercise applications could enhance self-efficacy by assisting users in overcoming obstacles to exercise, potentially leading to improved health outcomes such as BMI.

Based on the findings, while smart city applications offer potential benefits for enhancing physical activity and improving health results, further research is necessary to achieve a comprehensive understanding of their mechanisms and long-term effects.

2.6.2.3 Critical Review of Existing Literature

The studies about the usage of health applications have their strengths and limitations. This study starts by outlining the strengths. The numerous studies on the usage of health applications rely on real-world evidence and user experiences, presenting valuable understandings into how such technologies operate in practise (Montgomery et al. 2021; O'Brien et al. 2020).

Researchers frequently examine health applications amongst diverse populations, such as varying age groups, socioeconomic standings, and health conditions (Birkhoff and Smeltzer 2017; Zelmer et al. 2018). This range of approaches contributes to a more complete comprehension of the impact and usefulness of health applications (Birkhoff and Smeltzer 2017; Zelmer et al. 2018).

A common practice is to combine quantitative and qualitative research methods (Mayer et al. 2019). This dual approach enables researchers to obtain both statistical data and refined perspectives on users' experiences, preferences, and difficulties (Mayer et al. 2019).

Longitudinal designs are employed in certain studies to monitor individuals' engagement with health applications over an extended period (Baretta et al. 2019). Such an approach furnishes essential data on user engagement and the long-term impact of the application.

The integration of theoretical frameworks is also vital in such studies. Many studies utilize well-established theoretical frameworks, such as the UTAUT (Garavand et al. 2019) or the HBM (Alharbi et al. 2022), to strengthen the theoretical basis of the research.

These were the strengths, but these studies also have their limitations. Some previous studies have only looked at a limited number of databases, potentially missing a wider range of relevant literature. In addition, the inclusion of studies that rely on self-reported physical activity data is prone to bias (Sallis and Saelens 2000). Self-reporting methods are known for their inherent subjectivity, which can affect the accuracy and reliability of the information collected (Sallis and Saelens 2000).

A significant limitation is the temporal scope of the reviews. The most recent comprehensive review, conducted in 2019 by Romeo et al, summarises findings up to that point. Given the exponential growth in the field of smartphone interventions for physical activity (Müller et al. 2018), the evidence base has expanded significantly since 2019. This temporal gap highlights the need for ongoing research efforts to capture the latest advances and emerging trends.

The exponential growth observed in the field, as highlighted by (Müller et al. 2018), requires a proactive approach to keep abreast of the latest developments. The sheer volume of new interventions, technologies and evidence requires a continuous cycle of research and updates. As highlighted by (Romeo et al. 2019), the imperative for smartphone intervention research is to stay current and reflective of the evolving landscape.

2.6.2.4 Emerging Trends and Innovations

1. Integration of Artificial Intelligence (AI) and Machine Learning (ML):

Health applications are increasingly incorporating AI and ML algorithms to provide personalized insights, predictions, and recommendations (Xu et al. 2021). These technologies can analyse large datasets to offer tailored health and wellness suggestions based on individual user behaviour and health metrics.

2. Telemedicine Integration:

The integration of health applications with telemedicine services allows users to connect with healthcare professionals remotely (Weinstein et al. 2014). This trend has gained momentum, especially in response to the increased demand for virtual healthcare services (Weinstein et al. 2014).

3. Wearable Technology Integration:

Health applications are often designed to work in conjunction with wearable devices, such as fitness trackers and smartwatches (Gay and Leijdekkers 2015). This integration enables more accurate monitoring of health metrics, including physical activity, heart rate, and sleep patterns (Gay and Leijdekkers 2015).

4. Behavioural Change Techniques:

Many health applications are adopting evidence-based behavioural change techniques to motivate users to adopt and sustain healthy behaviours (Edwards et al. 2016). This includes features like goal setting, feedback mechanisms, and gamification elements to enhance user engagement (Edwards et al. 2016).

5. Mental Health and Well-being Focus:

There is a growing emphasis on mental health and well-being within health applications (Eisenstadt et al. 2021). Applications offering meditation, stress management, and mood tracking functionalities aim to address the holistic health needs of users (Eisenstadt et al. 2021).

6. Digital Therapeutics:

The emergence of digital therapeutics involves the development of health applications that deliver evidence-based therapeutic interventions (Hong et al. 2021). These applications often go beyond general health promotion to provide targeted treatments for specific medical conditions (Hong et al. 2021).

7. Augmented Reality (AR) and Virtual Reality (VR):

Some health applications leverage AR and VR technologies to enhance user experiences (Ferguson et al. 2015). This can include immersive simulations for rehabilitation exercises, virtual health coaching, or guided procedures for specific medical conditions (Ferguson et al. 2015).

8. Blockchain for Health Data Security:

The use of blockchain technology is gaining attention for securing health data in applications (Yaqoob et al. 2022). Blockchain can enhance data integrity, privacy, and security, addressing concerns related to the confidentiality of personal health information (Yaqoob et al. 2022).

9. Nutrition and Diet Tracking:

Health applications focusing on nutrition and diet tracking are evolving to provide more sophisticated features, including meal planning, personalized dietary recommendations, and integration with grocery shopping and delivery services (Flaherty et al. 2018). But “A significant effort from the user was required to use the mobile applications appropriately which may negatively influence user acceptability and subsequent utilisation” (Flaherty et al. 2018).

10. Community and Social Connectivity:

Health applications are incorporating social elements to foster community support and connectivity (Wyatt et al. 2021). This can include features such as forums, challenges, and social sharing to enhance user motivation and accountability (Wyatt et al. 2021).

11. Precision Health and Genomics:

Some health applications are exploring precision health approaches by integrating genomic data like the study of (Griebel et al. 2020). This allows for more personalized health recommendations based on an individual's genetic makeup (Griebel et al. 2020).

12. Accessibility and Inclusivity:

Emerging trends also highlight a focus on making health applications more accessible and inclusive, addressing the needs of diverse user groups, including those with disabilities or different language preferences (Ramos et al. 2021).

2.6.2.5 Consideration of Diverse Populations

1. Older Adults:

(Wildenbos et al. 2018) identified four primary categories of aging-related barriers that impact the usability of mHealth: cognition, motivation, physical ability, and perception. The effective and satisfactory utilization of mHealth by older adults faces challenges primarily stemming from cognitive and motivational barriers. Additionally, barriers related to physical ability and perception heighten the risk of user errors and impede the recognition of crucial interaction tasks. Complications arising from medical conditions, such as reduced eyesight linked to diabetes or impaired motor skills due to rheumatism, contribute to errors in user interaction.

2. Socioeconomic and Cultural Diversity:

Disparities in technology access and digital literacy contribute to uneven health application adoption across socioeconomic groups (Ramos et al. 2021). Cultural differences in health beliefs and preferences impact engagement (Ramos et al. 2021).

3. Health Conditions and Disabilities:

Individuals with chronic health conditions may have unique application requirements related to self-monitoring and communication with healthcare providers (Jones et al. 2018). Ensuring accessibility for individuals with disabilities remains a critical challenge (Jones et al. 2018).

4. Gender and Ethnicity Considerations:

Addressing gender-specific health needs and building trust in health applications among specific ethnic or racial groups are challenges (Bender et al. 2014). Language preferences and cultural nuances influence engagement (Bender et al. 2014). “Some disparities still exist, particularly among racial/ethnic groups with less education and whose primary language is not English” (Bender et al. 2014).

5. Community and Social Connectivity:

Importance of Community: Some studies underscore the importance of community and social connectivity features in health applications, facilitating engagement and support among users from diverse backgrounds (Mendiola et al. 2015).

2.6.3 User Willingness to Use Health Applications: Perceived Benefits and Barriers

2.6.3.1 Synthesis of Existing Knowledge

(Ahmad et al. 2022) have reviewed the topic “Willingness, perceived barriers and motivators in adopting mobile applications for health-related interventions among older adults”, their findings will be presented in the following.

Older adults expressed a willingness to use mobile applications if those applications came from a trusted and credible source, highlighting the importance of reliability and validity.

Continuous Improvements in Design and Personalization: Motivators for older adults included a positive response to continued improvements in the design of mobile application interfaces and personalised features tailored to their specific needs, suggesting a recognition of the value of user-centred design and customisation.

An obstacle commonly noted is the lack of awareness amongst older adults regarding the existence of mobile health applications. This emphasizes the necessity for directed educational campaigns that inform this age group about the range of health application options currently available.

The lack of sufficient technological aptitude has arisen as a substantial hindrance. Thus, demonstrating the significance of appreciating the varying degrees of digital competence amongst older individuals and bridging this gap to boost their ability to interact efficiently with healthcare technologies.

Barriers also included the apprehensions of older individuals regarding their capability to use mobile applications and time limitations. Addressing these issues may involve developing user-friendly interfaces and ensuring that health applications conform to the time constraints of older adults.

The lack of professional engagement has been recognised as a hindrance, advocating the integration of healthcare experts or the provision of support systems within health applications as potential solutions to bolster user participation.

Addressing trust and privacy worries is critical as they were significant obstacles to adoption. Building user trust amongst older adults means putting in place stringent privacy protocols and being open about data security to promote confidence.

The scoping review presents a multifaceted scenario where hypothesized advantages, such as reliability and bespoke attributes, correspond with the readiness of elderly individuals to use health applications. Nevertheless, limitations, including technical complexities and privacy apprehensions, emphasize the significance of focused interventions. Future strategies should prioritise improving technological literacy, addressing time constraints, and incorporating user-friendly features while maintaining trustworthiness and privacy to optimise the acceptance and regular use of health applications among older adults. Identification of key Theoretical Domains Framework (TDF) domains, specifically technological skills, beliefs

about consequences, and memory, attention, and decision processes, provides a strategic framework for designing effective interventions to change behaviour in this population.

Also, (Litman et al. 2015) analysed the topic “Mobile Exercise Applications and Increased Leisure Time Exercise Activity”. Their findings will be presented in the following.

Current users of exercise applications recorded markedly greater levels of physical activity compared to those who do not use them as well as those who used them in the past. This suggests a constructive correlation between the use of exercise applications and increased involvement in physical activity, thus fulfilling the primary goal of these programmes.

Higher Total Metabolic Equivalent of Task (MET) Expenditures: The study revealed that present application users demonstrated greater total leisure time MET expenditures, comprising walking and vigorous exercise, than those who ceased application use or never used applications. This suggests a promising potential for an overall increase in energy expenditure through physical activity supported by applications.

Current application users showed a lower BMI compared to past users and non-users. Technical term abbreviations were explained upon the first usage. This correlation was influenced by enhanced exercise levels and self-efficacy, indicating that exercise applications could contribute to healthier body weight outcomes.

The study indicated a mediation effect, suggesting that increased exercise levels and self-efficacy mediate the relationship between application use and lower BMI. This highlights the potential influence of exercise application use on individuals' exercise behaviour and perceived ability to participate in physical activity.

The impact of application usage on BMI was influenced by users' perceived obstacles to physical activity. This implies that surmounting these hindrances is a vital aspect of exercise application efficacy and tackling them might boost user involvement and health results.

The research presents convincing evidence of the presumed advantages linked to the usage of fitness applications. Individuals who utilise these applications are more likely to participate in greater physical activity throughout their leisure time, thereby leading to advantageous health outcomes, including a reduced BMI. The outcomes emphasise the role of fitness applications in overcoming hurdles to exercise, especially by increasing self-efficacy. The research promotes the idea of exercise applications as systems for delivering interventions and highlights the significance of integrating theory-driven approaches to improve their efficacy. These findings augment our understanding of how exercise applications can have a favourable impact on exercise behaviour and health results, forming a basis for potential interventions and improvements in application design in the future.

2.6.3.2 Comparative Analysis

(Ahmad et al. 2022) study finds that elderly individuals expressed their willingness to employ mobile applications for health observation and management purposes. Specifically, they were more inclined to use such applications if they were from a trusted source and possessed valid credentials.

Barriers encountered by older adults encompass an absence of awareness regarding mobile health applications, insufficient technological prowess, perceived inability, time constraints, absence of professional presence, and concerns related to trust and privacy.

Prominent barriers were identified among older adults about digital literacy, with a lack of technological skills being a key factor.

The belief that barriers were linked to consequences, memory, attention, and decision-making processes highlights the need to address cognitive aspects when designing mobile health interventions.

The study emphasises the potential for creating mobile applications to aid older individuals in health management but acknowledges the requirement to tackle precise hindrances. To effectively engage with the target group, it is advisable to employ behavioural change techniques that focus on technological proficiency, belief systems, and cognitive processes.

Meanwhile, Litman et al.´s (2015) study finds that individuals who utilise exercise applications, including both present and previous users, exhibited a greater inclination towards engaging in physical activity during leisure time in comparison to those who do not use such applications.

Perceived exercise barriers moderated the impact of barriers, underscoring the need to overcome obstacles to boost the efficacy of exercise applications.

Current application users reported higher total MET expenditures, a lower BMI, and increased self-efficacy than non-users and past users.

The study highlighted the significance of exercise applications in surmounting hindrances to physical activity, leading to augmented self-assurance and better well-being results.

Exercise applications have proven to be effective means to encourage physical activity during leisure time, with potential advantages for various demographic groups. Enhancing self-confidence and overcoming hindrances are recognised as crucial factors in maximising application efficiency.

Both studies highlight the significance of tackling hindrances for proficient application involvement, be it linked to technical abilities (older individuals) or general barriers to fitness (exercise application users).

The determination to engage with the application is impacted by factors like dependability (older individuals) and proficient application utilization (exercise application users).

The demographic groups exhibit differences (in the form of older adults as opposed to those from mixed backgrounds), indicating fluctuations in challenges and motivating factors about the utilization of health applications.

The various impediments and catalysts are unique and reflect the particular traits and predilections of each separate group.

A comparison of various demographic groups indicates nuanced insights into their willingness, barriers, and motivators. Although trust and overcoming barriers emerge as common themes, tailored interventions are essential due to the unique characteristics of each group to foster optimal engagement with health and exercise applications. Future research and interventions should consider these distinctions to enhance the effectiveness of technology-driven health solutions.

2.6.3.3 Implications for User Engagement

Based on these studies, the adoption of health applications is influenced by perceived benefits and barriers that shape users' initial willingness to engage with these applications. The adoption phase is positively impacted by trustworthy sourcing and valid credentials, establishing a foundation for user acceptance. However, potential barriers to wider adoption of health applications include insufficient awareness and technological skills, necessitating targeted educational initiatives to bridge these gaps.

Sustained usage of health applications depends on consistent positive experiences and features that align with user needs. Continuous enhancements in design and tailored characteristics aid in sustained engagement, while improved self-efficacy and exercise levels, demonstrated in the exercise application study, can lead to extended application usage for health upkeep. On the contrary, perceived obstacles such as technological difficulties and privacy concerns could result in disengagement gradually, underlining the significance of tackling these problems to ensure continuous user involvement.

The effectiveness of health applications in promoting positive health behaviours is influenced by their capacity to confer tangible benefits and surmount hindrances. The increased physical activity reduced BMI, and improved health outcomes observed in the exercise application study exemplify the potential impact of health applications on behaviour modification. Technological barriers, belief systems, and concerns around privacy could pose a hindrance to overall effectiveness, underscoring the importance of addressing these barriers to maximise the positive impact on health behaviours.

Tailored strategies are imperative to enhance user engagement, and personalisation features must be developed to meet the specific needs and preferences of certain demographic groups, such as older adults. Educational programmes focused on raising awareness and enhancing technical competencies can counter obstacles to application adoption and foster persistent usage. Incorporating behaviour change methods that address vital domains outlined in research, like technological proficiency and belief structures, could significantly augment the efficiency of healthcare applications.

Continuous improvement is essential to optimize user engagement with health applications. Developers should embrace an iterative design process, integrating user feedback and continuously enhancing features to keep up with evolving user expectations. Regular evaluations of application effectiveness, taking into account perceived benefits and barriers, should steer updates to guarantee ongoing relevance and impact.

Privacy and trust are critical factors in user engagement. Establishing transparent communication regarding data security measures can mitigate privacy concerns, thereby cultivating trust and augmenting the overall efficacy of health applications.

To ensure successful adoption, sustained usage, and general effectiveness of health applications in promoting positive health behaviours, identifying perceived advantages and obstacles is pivotal. Ultimately, addressing these factors is crucial for their optimal implementation. Future research ought to concentrate on demographic-specific investigations to customize health applications more successfully for diverse user clusters and evaluate the long-term effects of these applications on variations in conduct and health consequences.

2.7 Research on Technology Acceptance

2.7.1 UTAUT2 Model

The Unified Theory of Acceptance and Use of Technology (UTAUT) model is a thorough framework that has significantly improved our understanding of technology adoption and acceptance (Venkatesh et al. 2012). UTAUT posits a range of key constructs that impact users' technology acceptance, such as Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions (Samuel Attuquayefio and Hilla Addo 2014). These constructs collectively provide insights into the factors that influence individuals' adoption and usage of technology (Samuel Attuquayefio and Hilla Addo 2014).

Performance Expectancy, a vital component of UTAUT, relates to users' perceptions of how a specific technology will improve their job performance and productivity (Samuel Attuquayefio and Hilla Addo

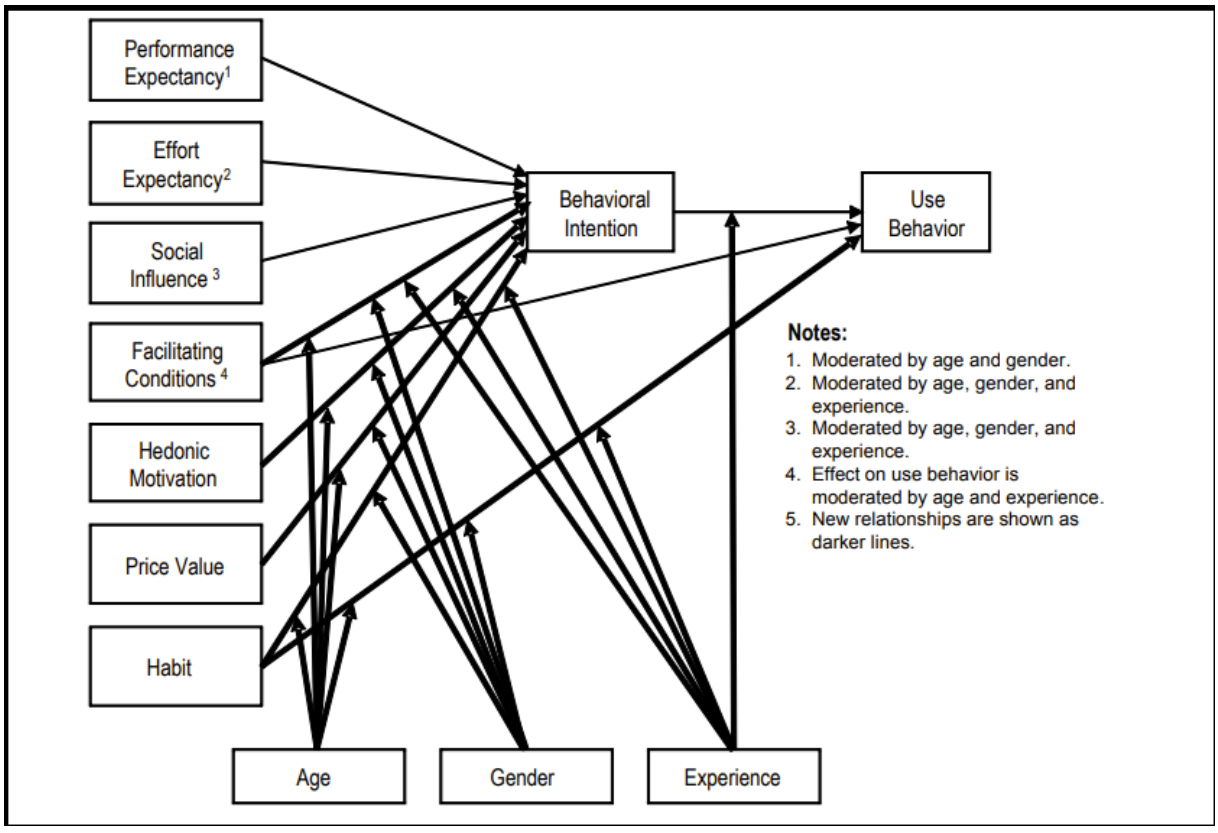
2014). In essence, it examines if users consider the technology as a helpful tool in enhancing their work-related tasks.

Effort Expectancy is a crucial construct that measures the ease of use of a technology (Samuel Attuquayefio and Hilla Addo 2014). The simpler and more user-friendly a technology is, the more likely individuals are to incorporate it into their routines (Samuel Attuquayefio and Hilla Addo 2014).

The UTAUT framework's Social Influence considers the impact of social factors on the adoption of technology (Samuel Attuquayefio and Hilla Addo 2014). Individuals' decisions can be influenced by the opinions and actions of those surrounding them.

Facilitating Conditions concern users' beliefs regarding organizational support for technology and the availability of necessary technical infrastructure (Samuel Attuquayefio and Hilla Addo 2014). This construct reflects the perceived readiness of the environment to facilitate technology use.

Furthermore, the UTAUT model acknowledges that specific crucial moderators, such as gender, age, experience, and voluntariness, may impact the association between these constructs and technology adoption (Venkatesh et al. 2012).



2 UTAUT2 Conceptual Model (Venkatesh et al. 2012)

UTAUT2, an extension of the original UTAUT model, incorporates three further constructs: Hedonic Motivation, Price Value, and Habit (Chang 2012). Figure 2 shows the Conceptual UTAUT2 Model.

Hedonic Motivation relates to the enjoyment and pleasure derived from technology usage, which plays a crucial factor in technology acceptance (Susan A. Brown and Viswanath Venkatesh 2005).

Price Value is significant in consumer settings where users frequently bear the cost of technology use. This construct examines the influence of cost and pricing structures on consumers' decisions to adopt technology (Chang 2012).

Habit theory assesses whether individuals have established technology-centric routines, underscoring the habitual aspect of technology adoption (Chang 2012).

UTAUT2 also acknowledges how individual differences, such as age, gender, and experience, affect the impact of these constructs on technology use and behavioural intention (Chang 2012). UTAUT2 has been shown to significantly enhance the model's explanatory power, especially regarding behavioural intention and technology use (Chang 2012).

Overall, the UTAUT and UTAUT2 models provide a comprehensive framework to comprehend the various factors that influence technology adoption and usage (Chang 2012). These models have offered useful perspectives on the dynamics of technology adoption, revealing the influence of different constructs and moderators on user behaviour and decision-making (Chang 2012).

2.7.2 Adapted UTAUT2 Model

Performance Expectancy (PE): In the context of promoting physical activity through smart city applications, performance expectancy refers to users' beliefs regarding the extent to which the use of the application can aid in their improvement of physical activity levels and health outcomes. It examines how users view the effectiveness and benefits of the application in promoting their well-being.

Effort Expectancy (EE): This dimension evaluates users' views on the usability and convenience of the smart city application. It considers aspects like the application's user-friendliness, ease of interaction, and overall effectiveness in increasing physical activity engagement among users.

Social influence (SI): Concerning smart city applications, social influence refers to the effect of external factors, including peers, family, and social norms, on the users' inclination towards using the application for physical activities. It examines the influence of social support and societal expectations on the users' tendencies to adopt and maintain the usage of the application.

Facilitating Conditions (FC): This dimension pertains to the accessibility of vital resources, including technology infrastructure and support, which empower users to utilise the smart city application effectively. It examines the impact of the availability of facilitating conditions on users' involvement with the application.

Hedonic Motivation: The emotional satisfaction and enjoyment that users experience when using the smart city application. This aspect acknowledges the significance of pleasure and amusement in shaping the intention of users to adopt and use the application consistently.

Habit: Habit plays a vital role in determining users' continued engagement with the smart city application. It depends on the degree to which they incorporate application usage into their daily routines and habitual behaviours. Therefore, it is crucial to analyse and understand users' habitual actions to encourage long-term engagement.

Behavioural Intention (BI): In the context of the study, BI refers to users' intentions to participate in physical activities via the smart city application. The research aims to establish to what degree users plan to utilize the application for their physical health, taking into consideration their perceptions of performance expectancy, effort expectancy, social influence, and facilitating conditions.

Actual Use (AU): This dimension concentrates on users' factual usage behaviour of the smart city application for physical activity. It assesses how often and regularly users utilise the application and whether their behaviour conforms to their original intentions.

Moderating Variables: This research incorporates supplementary moderating variables that potentially affect the correlations between the dimensions of the UTAUT framework. These variables may consist

of demographic attributes (age, gender, socioeconomic status), previous involvement with comparable applications, and individual health objectives.

2.8 Research on Health

2.8.1 Health Belief Model

The Health Belief Model (HBM) is a well-established psychological framework that seeks to elucidate the factors that influence individuals' adoption of health behaviours, particularly their decisions to seek medical care (C.C. and Prathap 2020). The model has received considerable attention in the academic literature (C.C. and Prathap 2020; Hsieh 2023) and provides valuable insights into the dynamics of health-related decision-making.

At its core, HBM posits that health behaviour adoption is influenced by several critical components. First, individuals' beliefs about the perceived threat of a health problem play a pivotal role in shaping their actions (Hsieh 2023; Y Zhang et al. 2019). In essence, if individuals perceive a particular health problem as a genuine threat to their overall well-being, they are more likely to take proactive steps to address it.

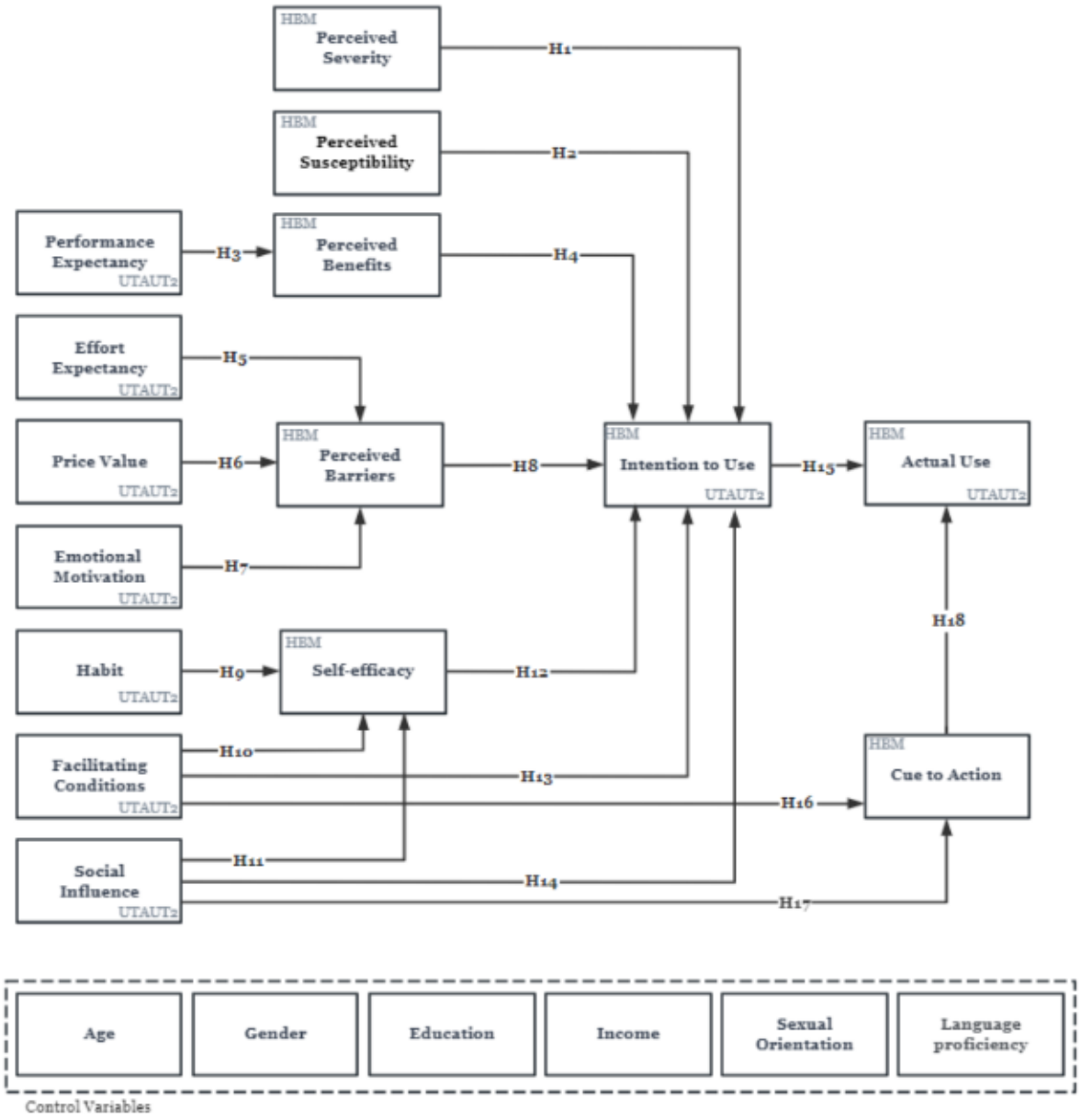
Second, HBM emphasises the importance of individuals' beliefs about the positive outcomes that will result from adopting a particular health behaviour (Hsieh 2023; Melzner et al. 2014). This aspect highlights that understanding the potential benefits of engaging in health-related behaviour serves as an important motivator.

In addition, HBM recognises the existence of perceived barriers that may prevent individuals from participating in health behaviours (Hsieh 2023; Melzner et al. 2014). These barriers cover a broad spectrum and include factors such as psychological, time, effort, or financial costs. Overcoming these barriers is often a critical step in the process of behaviour change (Melzner et al. 2014).

Finally, self-efficacy is a fundamental concept within HBM and refers to an individual's belief in his or her ability to perform a particular behaviour effectively (Hsieh 2023; Melzner et al. 2014). High self-efficacy is associated with increased confidence in one's ability to successfully adopt and maintain a health-related behaviour (Hsieh 2023; Melzner et al. 2014).

In summary, the Health Belief Model provides a robust framework for understanding the complex interplay of factors that influence individuals' decisions to adopt health behaviours. It highlights the importance of perceived threat, belief in positive outcomes, perceived barriers, and self-efficacy in shaping health-related decisions. This model has had a significant impact on the field of health psychology and continues to inform research and interventions aimed at promoting healthy behaviours.

2.8.2 Influence on the UTAUT2 Model



3 Concept of a new model connecting UTAUT2 and HBM (Rongbin Yang et al. 2023)

The UTAUT2 and the HBM were developed for separate contexts, with UTAUT2 centred on the acceptance of novel technologies and HBM examining health-related behaviours. However, despite their disparate origins, there are compelling similarities and complementary elements between the models, which lead to their harmonious integration in some research contexts. Figure 3 shows a concept of a new model done by Rongbin Yang et al. (2023), trying to connect the HBM model to UTAUT2.

2.8.2.1 Shared Emphasis on Perceptions

A significant similarity is the shared emphasis on an individual's perception as a crucial determinant of behavioural change. The UTAUT2 model encapsulates this concept in the performance expectancy,

which measures the user's opinion of the technology's usefulness and advantages (Rongbin Yang et al. 2023). Similarly, the Health Belief Model identifies perceived benefits as a significant factor affecting health-related conduct (Rongbin Yang et al. 2023). This comparison highlights the crucial part that personal perceptions play in shaping attitudes and behaviours, whether it is regarding the adoption of technology or making decisions related to health (Rongbin Yang et al. 2023).

2.8.2.2 Complementary Factors

Additionally, the Health Belief Model and UTAUT2 model complement each other (Rongbin Yang et al. 2023). The former covers general factors, like perceived barriers, which hinder adopting health-enhancing behaviours (Rongbin Yang et al. 2023). The latter, on the other hand, specifies those factors within the IT adoption context, like effort expectancy (Rongbin Yang et al. 2023). This alignment indicates that although HBM offers a wide-ranging view of perceived obstacles, UTAUT2 enhances and situates these challenges within the particular sphere of IT adoption (Rongbin Yang et al. 2023).

2.8.2.3 Integrated Frameworks in IT-Related Health Research

Scholars have recognised the synergies between UTAUT2 and HBM and proposed integrated frameworks to explore the factors affecting the adoption of health-related technologies (Rongbin Yang et al. 2023). The framework aims to provide insights into the systematic, structured, and holistic decision-making process involved in adopting such technologies. Combining both models, (Melzner et al. 2014) introduced a comprehensive framework to understand the factors influencing the adoption of mobile healthcare applications. Likewise, the UTAUT model was broadened by (Y Zhang et al. 2019) with the incorporation of the perceived threats concept from the HBM.

This amplifies the theoretical underpinnings of research and establishes an extensive comprehension of the intricate interplay between technological integration and health-related behaviours as noted by (Rongbin Yang et al. 2023). In the results sections, the impact of these integrated models will be applied to examine user acceptance and engagement of the Living Cities application, providing a detailed perspective on the factors that influence it.

2.9 Hypotheses

Building upon the research questions outlined earlier, this study formulates hypotheses that guide the investigation into the relationships between smart city applications, user motivations, physical activity engagement, and health outcomes. These hypotheses are designed to test specific conjectures derived from the theoretical framework and literature review, shedding light on the potential impact of these applications on urban residents' behaviour and well-being.

Hypothesis 1:

There is a clear and significant correlation between the strategic use of gamification features in smart city applications and increased user engagement in physical activities. This hypothesis suggests that applications that incorporate dynamic gamification elements such as challenges, rewards, and competitive components can generate a stronger and more sustained motivation among users to engage in physical activities in an urban setting. The hypothesis is based on the premise that the gamification framework functions not only as an interactive tool but also as a mechanism for transformation, changing users' views on exercise from a monotonous duty to an immersive and purposeful activity. By incorporating challenges that establish structured goal setting, incentives that act as motivational rewards, and competition that introduces a social and collaborative aspect, smart city applications are anticipated to serve as significant catalysts in stimulating and perpetuating users' devotion to wholesome and vigorous

city lifestyles. This hypothesis is in line with current literature that underscores the motivating potential of gamification in promoting favourable behavioural shifts. The objective of this study is to provide empirical support to the developing conversation on how technology, urban lifestyles and physical well-being intersect.

Hypothesis 2:

The second hypothesis suggests that the exercise routines of users are more significantly influenced by smart city applications, which combine functionalities such as tracking activities, setting goals, and providing health insights, compared to applications that provide generic content. This assertion is based on the belief that incorporating customized and health-focused features offers users a more stimulating and meaningful encounter, which, in turn, drives their adherence to a scheduled exercise routine.

The hypothesis assumes that activity tracing acts as a trigger for augmented self-awareness, empowering users to monitor their physical pursuits and advancement over time. The implementation of goal-setting mechanisms heightens motivation as users strive to attain and exceed predetermined targets, leading to a sense of accomplishment and continued dedication. Health insights, comprising information on physical wellness and the possible hazards associated with a sedentary lifestyle, contribute to an educational factor, empowering users to make informed choices about their health.

The premise is that these bespoke and adaptable characteristics produce a diverse user experience that surpasses the restrictions of standard content. Although standard content may provide elementary information, it lacks bespoke direction and interactive components, which have been verified to enhance user engagement in health-related applications.

Empirical evidence may indicate a correlation between integrating certain features and a rise in user compliance with workout regimens. Furthermore, it proposes that users perceive more worth in applications that surpass generic content and strive to offer a more individualised, goal-oriented, and health-centric experience. The potential repercussions of this hypothesis surpass the technological domain, examining the complex intricacies of user conduct and the subtle interactions among application features.

Hypothesis 3:

This hypothesis posits a substantial and affirmative correlation between users' interaction with smart city applications and their self-reported boost in physical activity levels. It is suggested that individuals who actively engage with the various features of the application, keep detailed records of their physical activities, and eagerly participate in gamified challenges are likely to see a significant increase in their overall physical activity levels during the study period. The hypothesis is based on the idea that prolonged and valuable engagement with the application promotes a feeling of responsibility, drive, and an increased understanding of one's physical health. Those who participate actively in gamified challenges are expected to demonstrate a more significant dedication to incorporating regular physical exercise into their day-to-day lives. This hypothesis is in line with previous research that highlights the significance of user engagement in determining the effectiveness of health-related applications. By analysing the relationship between users' interaction patterns and their reported physical activity level changes, this hypothesis aims to provide empirical insights into the ever-evolving field of smart city applications and their potential impact on stimulating active urban lifestyles.

Hypothesis 4:

This hypothesis proposes a favourable correlation between the integration of social interaction and collaborative characteristics in smart city applications and the enhancement of adherence to physical activity routines among users. It asserts that smart city applications that assist social engagement and

collaborative goal setting promote a greater sense of community and shared accomplishment. By creating links among users, these applications are anticipated to boost responsibility, drive, and a joint obligation to keep up with a regular workout plan. The hypothesis relies on the social character of physical movement and postulates that the community aspect supported by these applications will have a constructive impact on users' adherence to their workout routines. By providing a platform for shared goals, achievements, and encouragement, these applications are expected to have a crucial impact on extended participation in physical activities. The hypothesis corresponds with a burgeoning body of research, underscoring the influence of social support and community involvement on individual health behaviours. This hypothesis aims to provide valuable insights into the burgeoning field of health-enhancing urban technologies by examining the correlation between social features in smart city applications and users' compliance with physical activity.

Hypothesis 5:

This hypothesis proposes that user demographics, including age, gender, and socioeconomic status, could moderate the relationship between smart city applications and physical activity engagement. It suggests that certain features within these applications, which aim to promote healthier lifestyles, might be affected by the user's demographic characteristics. As individuals from various demographic groups may have specific preferences, motivations, and barriers associated with physical activity, the hypothesis suggests that the influence of smart city applications on behaviour modification will differ depending on distinct user segments. For example, certain features may be more desirable or effective for age groups, genders, or socio-economic backgrounds. Understanding these potential moderating effects is paramount to customising smart city applications to the varied requirements of urban populations and optimising their influence on promoting physical activity. This hypothesis seeks to provide nuanced insights into the design and implementation of health-enhancing technologies in urban settings by investigating the interplay between user demographics and the efficacy of smart city applications.

3 Research Methodology

3.1 Research Design

In the area of research design, the choice between quantitative and qualitative methods is a critical consideration. Traditionally, research into the acceptance of information systems has predominantly used quantitative methods, as highlighted by (Jim Hughes and Steven Jones 2003). However, it is imperative to recognise the evolving landscape of qualitative research in tandem with technological advances.

Qualitative research, as noted by (Gibbs et al. 2002), is undergoing a transformative journey that is significantly shaping the processes of data collection and analysis. The integration of qualitative approaches into the study of information systems acceptance opens avenues for a more nuanced understanding of users' perceptions, motivations, and barriers. This development reflects a recognition of the dynamic interplay between technology and human experience. It offers valuable insights that complement the quantitative perspectives often employed in the field. As research methodologies continue to adapt to the complexities of the digital age, the incorporation of qualitative methods is a crucial dimension in unravelling the intricacies of information systems acceptance.

3.2 Data Collection Methods

In the context of data collection for this research, a deliberate choice was made to use audio recording as a methodological strategy during the qualitative interview phase. This deliberate choice was based on the recognition of the inherent value attributed to audio recordings in preserving the authenticity and depth of participants' responses.

The use of audio recordings offers a multifaceted approach to data collection, allowing for the careful capture of participants' verbal expressions, tonal nuances and contextual subtleties that may be perceptibly obscured in transcribed text alone. This methodological choice is consistent with the interpretive nature of qualitative research, which seeks to holistically capture the lived experiences and nuanced perspectives of participants.

By opting for audio recordings, the research seeks to overcome the limitations associated with written transcripts, providing a richer and more immersive dataset for subsequent analysis. This nuanced and comprehensive approach serves as a deliberate methodological choice that enhances the authenticity and depth of the qualitative data collected, thereby strengthening the robustness of the subsequent analysis within the broader framework of the research objectives.

3.3 Study Population and Sample Selection

The study population was chosen based on specific criteria to ensure a focused analysis of the reception and usage of the Living Cities application. The criteria were designed with care to include individuals who could actively participate in the application and offer diverse perspectives on its functions.

Inclusion Criteria:

Possession of a Smartphone: Ownership of a smartphone was required for participation, as the Living Cities application is designed for mobile devices. This prerequisite ensured that all participants possessed the necessary technological capability to engage with the application.

Opportunity to Visit Ulm: The investigation concentrated on individuals who had the opportunity to visit Ulm, underscoring the application's applicability to their immediate surroundings. This criterion sought to harmonize the participants' encounters with the application's functions, especially those linked to open-air activities within the locality.

No Major Health Disabilities: Participants without major health disabilities were selected to ensure that they could engage in physical activities such as walking or jogging, in line with the application's core functions. This criterion contributed to examining the application's effect on individuals with different health conditions.

For qualitative research, it is commonly recommended to have a sample size of 10 to 15 participants to achieve data saturation, enabling the acquisition of thematic richness while avoiding overwhelming the research team. In the case of this study, we opted to work within this participant range due to the considerable depth and richness of insights sought from participants' experiences with the Living Cities application.

Ethical standards were maintained throughout the recruitment process and study. Informed consent forms were provided to the participants, outlining the study's purpose, and procedures. Confidentiality and voluntary participation were emphasized to comply with ethical principles.

3.4 Data Analysis Techniques

The data analysis process employed in this study followed a rigorous qualitative content analysis methodology. Using NVivo12 software, the analysis followed both coding strategies as described by (Mackey and Gass 2012). This approach facilitated a systematic exploration of the interview data and ensured a comprehensive examination of participants' responses.

The first step involved the creation of a coding framework based on a synthesis of constructs and definitions extracted from the existing literature. This framework served as the basis for categorising the interview statements. The subsequent coding phase involved careful alignment of statements with predefined categories, while also accommodating novel categories for expressions not readily encapsulated by existing constructs.

The systematic coding framework, integrated with the capabilities of NVivo12, facilitated a thorough exploration of the qualitative data. The resulting dataset, organised through a coding process, provided the basis for robust findings and meaningful interpretations. The chosen methodology contributes to the validity and reliability of the study's findings, allowing for a comprehensive understanding of the factors influencing smart speaker adoption in the context of the study.

4 Results

4.1 Overview of the Smart City Application Living Cities

4.1.1 Mobile Application Overview

The Living Cities mobile application was developed to enhance the health and physical activity levels of Ulm's inhabitants, a German city. To accomplish this, the application employs gamification, incorporating game elements to effectively engage and motivate its users. Emphasised features include offering rewards to users, promoting environmental awareness, as well as encouraging active participation.

Gamification is a core strategy that incorporates game elements into non-game environments, including health and wellness applications. In the Living Cities application, this approach is evident in the inclusion of features such as a points system, challenges, and rewards. These elements are intentionally designed to tap into users' intrinsic motivations, creating a more enjoyable and engaging experience for health-promoting activities.

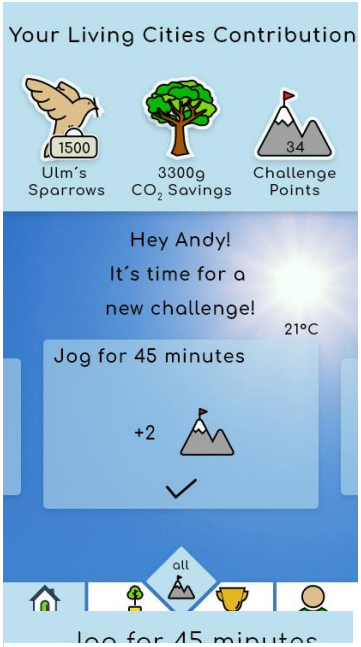
By providing tangible rewards, such as points and vouchers, the application establishes a constructive feedback system that reinforces desired behaviours. This approach is consistent with motivational theories that include reinforcement elements, which can aid in cultivating favourable habits over time.

Incentivising user participation is a core element of the Living Cities application's gamification strategy. Additionally, fostering active engagement is a paramount objective of the Living Cities application. Challenges and interactive features encourage users to engage in physical activity, aimed at improving their health and well-being. The social and competitive nature of these challenges also cultivates a sense of community and friendly competition, thereby furthering user engagement with the application.

The Living Cities application distinguishes itself through its promotion of environmental awareness by integrating information and activities related to the environment.

The Living Cities application harnesses the power of gamification to enhance user motivation and engagement. Combining health promotion with game elements, the application aims to make physical activity a sustainable and enjoyable aspect of users' lives, while also promoting community and environmental awareness.

4.1.2 Points System



4 Home Screen Living Cities

5 Running Challenge Living Cities

The application implements a comprehensive points system consisting of three different types of points, each tailored to encourage specific behaviours and interactions.

One of the main forms of points offered by the application is Challenge Points. These points are earned by completing various challenges provided to users. Users are presented with a variety of challenges, including activities such as jogging, walking, and cycling for a pre-determined amount of time. Upon successful completion of a challenge, users are awarded Challenge Points, with the number of points earned correlating to the initial difficulty and duration of the challenge.

Notably, the application also features collaborative challenges that involve partnerships with local businesses in the city of Ulm. For example, challenges may involve visiting locations such as the Donaubad public swimming pool for a set period. Users who complete these partnered challenges earn Sparrow Points as well as Challenge Points.

Sparrow Points, while closely related to Challenge Points, have a unique role within the application. These points are earned in conjunction with challenges involving partners in the city of Ulm, encouraging not only individual physical activity but also community engagement. For example, completing a challenge such as swimming for 30 minutes in the Donaubad will result in the acquisition of Sparrow Points. The accumulation of one hundred Sparrow Points is linked to practical benefits, such as small discounts offered by the application's partner businesses.

The application extends its rewards system into the realm of environmental awareness with the introduction of CO2 points. These points are earned by users who participate in challenges while maintaining a carbon-neutral travel approach. In other words, users accumulate CO2 Points by travelling to and from challenges without generating carbon emissions. Notably, CO2 points act not only as an incentive but also as a measure of environmental impact reduction. These points promote a sense of collective responsibility by allowing users to compare their carbon footprint with their peers through a leader board system.

In summary, this mobile application uses a multi-faceted points system to incentivise users to engage in physical activity, encourage collaboration with local partners, and promote environmental awareness by quantifying individual carbon footprint reductions. The dynamic interplay between Challenge Points, Sparrow Points and CO2 Points underlines the application's innovative and holistic approach to promoting physical activity and well-being in urban environments.

4.2 Dataset

The examined dataset offers an exhaustive and insightful investigation into users' encounters with the health application, derived from twenty-two interviews with twelve participants. The dataset's distinctive trait is its richness due to the multifarious perspectives collected from individuals who recently acquired the application. The interviews comprise the feedback and impressions of twelve participants who were

in the early stages of familiarising themselves with the application, providing valuable insights into their initial interactions, expectations, and early experiences.

To enhance the dataset, we conducted ten interviews with the participants who engaged with the application for an extended period of approximately three weeks. This temporal dimension imparts a greater depth to the dataset, enabling a nuanced comprehension of users' perceptions and evolving experiences during an extended duration of use.

The dataset encompasses a varied cohort of participants, guaranteeing a comprehensive cross-section of user demographics, preferences, and technological backgrounds. This inclusivity fortifies and advances the robustness and generalisability of the findings.

The dataset encompasses a diverse range of user views, gleaned from twenty-two interviews, thereby permitting a complete exploration of their experiences. The incorporation of both affirmative and critical feedback guarantees an impartial and thorough examination.

As the dataset develops, it presents a distinctive chance to extract valuable patterns, evaluate the application's adaptability over time, and create user-focused suggestions to enhance it. Incorporating the perspectives of participants at various phases of their interaction with the application enhances the breadth and depth of the findings, resulting in a more nuanced comprehension of user actions and preferences.

In summary, the dataset's careful composition, which incorporates participants at different stages of application interaction, offers a wealth of information for analysis. This ensures that the study's outcomes are based on diverse user experiences and temporal dimensions. Furthermore, this approach improves the dataset's usefulness, making it a valuable resource for deriving actionable insights and informing future health application iterations.

4.3 Participants Demographic Background

4.3.1 Demographic Background of Participants

The study involved a diverse group of participants with a range of demographic characteristics. These characteristics are described below:

Table 1 Participants

	Age	Occupation	Academic	gender	marital status	residential area
P1	27	student	Bachelor’s degree	female	single	City
P2	25	student	abitur	male	single	small town
P3	24	electrician looking for work	abitur	male	single	small town
P4	24	soldier on time	abitur	male	single	City
P5	25	software engineer	vocational school	male	single	rural area

P6	26	student	abitur	male	single	City
P7	59	telephone switch-board/reception	vocational school	female	divorced	rural area
P8	54	business owner	vocational school	female	married	small town
P9	51	textile salesperson retail	vocational school	male	married	small town
P10	55	medical assistant	intermediate maturity	female	married	rural area
P11	57	master metalworker	master craftsman	male	married	rural area
P12	21	student	Bachelor’s degree	male	single	City

4.3.2 Gender

Of the twelve participants taking part in the study, a noteworthy aspect of the sample composition is the gender distribution, revealing a thought-provoking demographic facet. The gender distribution displayed a slight imbalance, with four participants identifying as female and eight participants as male. This distribution raises intriguing considerations about the representation of diverse gender groups within the research context.

4.3.3 Age

The sample of participants in this study showcased significant age diversity, representing various demographic groups. The distribution of ages contained a mixture of individuals, with five participants situated within the 21 to 25 age range, two participants in the 25 to 30 range, and five participants surpassing 50 years of age. Notably, no representation was found within the 30 to 50 age range, leading to distinct groupings in the 21 to 25 and the over 50 categories.

The interpretation of the study's findings is significantly influenced by understanding the age distribution among participants. The inclusion of participants from various age groups adds complexity to the analysis, as potential variations in technology adoption, health awareness, and preferences across generations must be considered. The prevalence of younger and older participants could provide insights into how distinct age cohorts engage with and perceive health-related mobile applications.

Due to the lack of participants in the 30 to 50 age range, it is crucial to acknowledge potential limitations in generalising findings to individuals within this demographic. Each age group is likely to possess distinctive perspectives, experiences and expectations concerning their interactions with the Living Cities application. The findings of the study may be more representative of the attitudes and behaviours of the younger and older age groups. Therefore, it is important to interpret the results with caution and carry out further targeted research exploring the excluded age range.

The diverse range of ages among the participants raises issues about age-related preferences and technological familiarity. Younger individuals, who are often more familiar with technology, may approach mobile applications with a different perspective compared to their older counterparts, who harbour varying levels of expectations for and comfort with digital tools.

4.3.4 Highest Educational Attainment

The study participants demonstrated a diverse array of educational backgrounds, indicative of a broad spectrum of academic accomplishments. The diversity in education was exemplified by a range of formal education levels, providing a finely detailed understanding of the participant group.

Among these, four participants held an Abitur, which serves as the fundamental qualification for university admission in the German education system. Additionally, two participants held a bachelor's degree. This subgroup of individuals with higher education backgrounds is likely to have brought distinct analytical and critical thinking skills to their engagement with the Living Cities application.

Three participants had finished vocational training, indicating a different educational path that often prioritises hands-on skills and practical expertise. The vocational experiences of this group could shape their approach towards technology and health-related applications, leading to exclusive perspectives in the study.

Additionally, two participants possessed lower secondary school leaving certificates, representing different educational attainments in the sample under study. Findings from this group might reveal how individuals with relatively lower formal education levels perceive and interact with mobile applications promoting health.

The educational diversity evidenced in the participant sample aligns with the wider societal landscape, in which individuals embark upon varied educational paths. This diversity is fundamental to the outside validity of the study, facilitating insights that can resonate with a wider array of individuals possessing diverse educational backgrounds.

Given the variance in educational backgrounds, it is essential to explore possible correlations between academic achievement and engagement with the Living Cities application. Increased education levels may affect the participants' capacity to understand and efficiently use the application's functionality. On the other hand, it is important to consider the diverse educational contexts when interpreting application-related behaviours, as individuals with vocational training or secondary school qualifications may have distinct viewpoints.

4.3.5 Primary Occupational Activity

The study participants exhibited diverse professional backgrounds, which provided numerous perspectives on integrating the Living Cities application into daily routines. Occupations of the participants spanned multiple sectors, highlighting a rich tapestry of experience within the cohort.

Additionally, four participants are occupied as students, representing an academic cohort. The participants' familiarity with digital tools could influence their engagement with technology and health-related applications. Consequently, their feedback could offer insights into the preferences of a younger audience.

In addition, the study's inclusivity and relevance across various professional realms were emphasized by the varied occupations displayed by the remaining participants. The range of occupations varied from a soldier, representing those with military experience, to an electrician, providing insights from a skilled trade viewpoint. The diversity was further compounded by a retail business owner, a textile salesman, a telephone operator, a metalworker, a healthcare assistant, and a software programmer.

The participants' professional variety added substantial depth to the study. Every profession has its unique bundle of abilities, viewpoints and day-to-day practices that mould how people from diverse professional backgrounds assimilate technologies promoting well-being into their lifestyles. Comprehending the distinct patterns and demands of various professions expands the relevance of the study's discoveries to a wider audience.

The occupations featured in the study provide valuable insights into the challenges and benefits of incorporating technology, particularly health-focused applications, across diverse professional environments. For instance, a software developer may possess a more nuanced understanding of application functionalities, whereas a medical assistant can offer valuable perspectives on health-related application usage in the healthcare industry.

Given the variety of jobs, it is important to investigate how the Living Cities application fits into the everyday lives and routines of people from various professional backgrounds. Participants' preferences and challenges in various occupations might guide future application design considerations, ensuring that the application caters to the varying demands and expectations of users from various professional backgrounds.

4.3.6 Marital Status

The study participants displayed various marital statuses, offering insight into how people with different relationship dynamics utilize health-promoting technologies. Although the diversity of marital statuses was somewhat limited, it still aided in comprehending the possible variations in application adoption and usage patterns that may be influenced by relationship dynamics.

4.3.7 Residential Area

The participants' residential areas were geographically diverse. Four participants lived in urban areas, four in small towns and four in rural areas. This diversity in geographical distribution covered a wide range of living environments.

This diverse demographic background illustrates the diverse nature of the study participants, which is particularly relevant when considering their engagement with the tested smart city application.

4.4 Research Findings

The thorough investigation of users' adoption and usage patterns of the Living Cities application, utilizing the UTAUT2 theoretical framework, has yielded detailed and refined understandings of participants' perceptions and experiences. This theoretical model, formulated to illuminate the intricacies of technology adoption, has been crucial in deciphering the complex dynamics that influence users' engagement with this health-enhancing application.

Using the UTAUT2 model, the study analysed various aspects of user behaviour, such as performance expectancy, effort expectancy, social influence, and hedonic motivation. This detailed comprehension has contributed to a comprehensive understanding of how users interact, engage, and derive benefits from the Living Cities application.

The efficiency of the UTAUT2 model in this context suggests its versatility in technology adoption scenarios, specifically in the field of health-oriented applications in the smart city environment. The increasing importance of technology in urban health initiatives underscores the significance of frameworks such as UTAUT2 in guiding research and enhancing the development of health-promoting applications for various user demographics.

In terms of performance expectancy did the users consistently report dissatisfaction with the application's effectiveness in enhancing physical activity, resulting in a significant disparity between their expectations and the application's intended objectives. Recognising that the Living Cities application may not be a suitable tool for promoting health and well-being emphasises the necessity of aligning user expectations with the application's features.

Participants expressed opinions on their health improvement such as, “Don't think so. So, it stayed the same. Maybe a little bit at the beginning” (P3). This demonstrates an initial interest in discovering how the application functions and a willingness to explore its capabilities. Several participants expressed their curiosity about the application and their desire to test it out and earn rewards. However, there was a unanimous agreement that the application did not significantly improve their level of physical activity. One participant stated, “But in general, I don't think it's led to me doing more sport now, it's stayed about the same” (P3).

These user perspectives highlight the necessity of precisely matching the application's features and functions with the users' expectations. The significance of enhancing the application to cater to the diverse motivations and preferences of its user base more proficiently cannot be overstated.

In terms of effort expectancy, the Living Cities application has received positive feedback for its user-friendly interface, as users have expressed admiration for its effortless navigation and smooth integration into their everyday activities. The perception of the application's user accessibility is a vital factor that can significantly enhance its potential for widespread use.

Users' feedback indicates that the application is user-friendly and straightforward to navigate, highlighting its capability to eliminate engagement barriers. The seamless alignment with daily routines suggests that the application is accepted as a convenient and accessible tool, boosting its frequent usage. This feedback on effort expectancy implies that the Living Cities application has effectively established an environment wherein users find it expedient to interact with the application, thereby fostering a more favourable user experience.

“Generally speaking, it's simple to use. I am quite good so far. You just have some things that don't work quite so well“ (P5).

The analysis indicated a lack of social influence on users' engagement with the Living Cities application. This highlights that users' decisions to interact with the application were mainly self-driven. Therefore, the Living Cities application effectively caters to individual motivations rather than relying on external pressures or social influences.

The discovery of insignificant social influence concurs with the notion that individuals' choices to accept and interact with health-related applications, like the Living Cities application, are typically driven by personal incentives and inherent factors. The prioritisation of autonomous engagement suggests that users are impelled by inner aspects such as personal health ambitions, individual choices, and the yearning for self-development. This feature is beneficial for the application as it implies that users are inclined to engage regularly, motivated by their ambitions rather than external factors.

“Maybe collect points together with others who have never actively done this before? Yes, it can be fun to collect points in a playful way” (P2).

Although there were positive experiences noted during testing, it is essential to address the technical and functional challenges that emerged. These factors adversely affected the user experience, impeding the application's ability to facilitate engagement. Notably, the application's failure caused reduced levels of engagement and highlighted critical areas requiring attention for a smoother and more reliable user experience.

Identification of technical issues and functional limitations highlights the need to address these challenges for enhanced facilitating conditions for users. Maintaining user trust and encouraging consistent engagement rely on a seamless and dependable application experience. Recognising these challenges provides valuable feedback for developers and stakeholders. Specific areas requiring improvement should be highlighted to create a more robust and user-friendly environment. Optimising the overall effectiveness and user satisfaction with the Living Cities application necessitates the addressing of facilitating conditions.

“Well, I've had that a few times when I've been running for half an hour and at some point, it stops and says yes, I've been running for 28 minutes, I can't even manage 30, although I've actually been running for longer than 30” (P5).

Technical disruptions which affect the enjoyment factor have been identified as a critical factor influencing users' motivation to consistently interact with the application. This highlights the significance of addressing both the functional components and emotional appeal of the application.

Acknowledging the influence of technical malfunctions on the level of satisfaction implies that users are driven not just by the application's practical benefit, but also by the general experience it offers. To that end, increasing the hedonic motivation of the Living Cities application necessitates attention not only to fixing technical glitches but also to crafting a captivating and gratifying user encounter. Developers can enhance user satisfaction and sustained engagement with the application by incorporating elements that promote enjoyment. This nuanced understanding highlights the importance of considering both functional and hedonic elements to foster sustained motivation and interaction with the application. The holistic approach required to optimize both functional and hedonic aspects is crucial for creating a comprehensive and effective health application.

“To be honest, it went badly. Yes, it did not work at all despite several attempts. And at our age, after two or three unsuccessful attempts, we lose the true desire” (P10).

The functionality irregularities and occasional user forgetfulness encountered while using the Living Cities application present a challenge for establishing a consistent usage pattern. This makes it necessary for the application to seamlessly integrate into users' daily routines, thus promoting habitual engagement.

The research findings indicate that users face difficulties in developing a consistent engagement or habit with the application, which suggests that the application may not be integrated smoothly into their everyday lives. Therefore, it is imperative to address the identified inconsistencies and enhance the user experience to make the Living Cities application an essential component of users' routines. This will ensure a seamless and more consistent interaction. Developers can promote the long-term effectiveness of the application in enhancing and maintaining health and well-being by aligning its functionalities with users' daily activities and by eliminating obstacles to consistent use. This fosters the formation of habits around the application.

“No. I tried it out at first and had fun using the application, but I stopped using it afterwards” (P3).

The significant scepticism amongst older participants about the application's efficacy, along with data protection concerns, highlights the likely age-related differences in acceptance. It is crucial to recognise these nuances for crafting the application's messaging and characteristics to better align with the requirements and expectations of diverse age groups. “Yes, I don't have that much faith in artificial intelligence, and I also see the danger that the power could be controlled in an impaired way. If you are not physically able to walk, you might be limited. That's why I have my reservations” (P7).

The research has revealed a variation in acceptance levels among diverse age groups, underscoring the necessity for specific interventions and customization according to age-related factors. Older participants, who initially manifested scepticism, may require targeted messaging to tackle their apprehensions and instil trust in the effectiveness of the application. This age-targeted customisation may involve accentuating privacy measures, presenting unambiguous particulars on data protection, and exhibiting triumphant anecdotes applicable to their populace.

Additionally, developers should aim for user-centric designs that cater to a broad range of users by taking into account different age groups' diverse needs and preferences. Ensuring that the Living Cities application is comprehensible and captivating for all age groups. Addressing age-related discrepancies in acceptance can enhance the application's inclusivity and efficacy among diverse demographic groups.

The study found that neither gender nor occupation had a significant impact on usage behaviour or application perception among participants. This uniform response across different demographic groups indicates that the Living Cities application has achieved universal appeal, resonating with users regardless of gender or professional background.

The findings suggest that the application's capabilities, layout, and general operation accommodate a wide audience and surpass gender-specific or occupation-based preferences. This inclusivity highlights the software's versatility and adjustability to the varying demands and tastes of individuals from diverse genders and occupations.

While the lack of substantial variances in usage patterns and user perception is encouraging, it is crucial to continue making deliberate efforts to preserve the universal appeal of the Living Cities application in future updates. Collecting consistent user feedback, conducting surveys, and performing usability testing can furnish valuable insights into shifting user expectations, guaranteeing that the application sustains its relevance and alluring qualities among diverse demographic groups.

Individuals who had prior experience with smartphone applications were able to integrate more smoothly with the features of the Living Cities application, indicating that their familiarity with common application functionalities had a positive effect on their overall user experience. This discovery highlights the necessity of taking into account users' varying levels of technological proficiency when designing and optimizing applications related to healthcare.

Although the impact of prior application experience was apparent, there is still scope for targeted interventions to aid users with less familiarity. By incorporating user tutorials, tooltips, or onboarding processes, individuals who may not be well-versed in navigating mobile applications can receive additional assistance, thus boosting their overall satisfaction and engagement with the Living Cities application. “My experience was difficult because I didn't read the explanation of the application. It is hard to get through without this initial page and I had to invest a lot of time to understand the application. I might not be able to find it anymore and that's why it was difficult for me to understand how the application works” (P8). Additionally, this insight informs strategies to bridge potential gaps in user experience based on varying levels of application familiarity.

Insights from the thorough examination of user behaviour provide valuable information on how participants interacted with the Living Cities application. This investigation reveals patterns in usage and also highlights the challenges and opportunities for improvement within the application's functionality.

By exploring each user's behaviour, the study uncovers subtle details about how individuals engaged with the application, revealing factors that influenced their usage patterns. The findings have implications for enhancing the application's features. This assessment surpasses mere quantitative measures

by presenting a qualitative analysis of users' experiences, challenges encountered, and possible improvement areas.

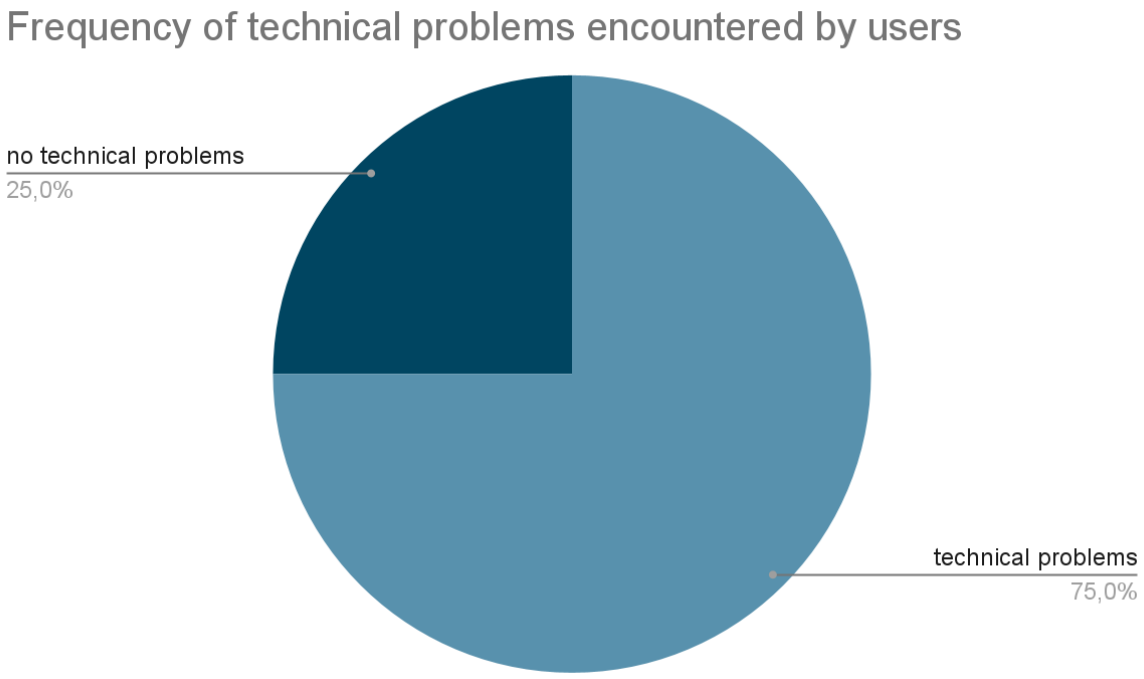
Improving the Living Cities application to better align with user preferences, expectations, and needs necessitates a deep understanding of user behaviour. The results of this analysis can guide the development of practical recommendations, which can shape the future evolution of the application to improve its ability to cater to the varied requirements and usage patterns of its targeted users.

Responses to application engagement indicated an average usage rate of two times per week. Nonetheless, sporadic instances of forgetting to use the application suggested a moderately unpredictable ingrained usage pattern. This variation in usage frequency highlights the requirement for strategic interventions to foster habitual application usage.

To enhance the consistent and integrated adoption of the Living Cities application into users' daily schedules, effective tactics may comprise personalized reminders, gamification features for regular check-ins, or the integration of a user-friendly monitoring system to encourage accountability. Occurrences of usage frequency provide valuable direction for improving the application's functions to meet users' preferences and habits, promoting lasting and routine interaction.

The evaluation of how users interacted with the Living Cities application revealed issues linked to the application's dependability and the exact monitoring of user activity. “I was surprised that the application didn't work well. The first time I used it” (P1). These problems have been recognised as major obstacles that negatively affect user involvement. Figure 6 visually shows the proportion of participants who encountered technical difficulties, emphasising the significance of these challenges to user experience. It is worth noting that technical problems were reported by nine out of twelve participants during the testing of Living Cities. It is interesting to note that the three participants who did not experience these types of problems were also the participants who reported forgetting about the application immediately.

Improving user engagement is vital; technical enhancements, monitoring refinement, and seamless user experience implementation are necessary to mitigate the issues identified. “No, because it has these flaws, and I can't rely on it at all” (P7). This comprehensive method will not only sustain user interest but also ensure a positive and trustworthy application experience. The graph depicted in Figure 6 provides a valuable reference point for comprehending the incidence of such challenges among participants, and thus strategizing targeted improvements aimed at optimizing user engagement with the Living Cities application.



6 The percentage of participants to encounter technical problems

An investigation into the intentions versus usage of the Living Cities application among participants unveiled a significant lack of alignment. Although they demonstrated a strong desire to use the application for physical exercise and health improvement, challenges with the application functionality hindered their ability to achieve these goals fully. Addressing the misalignment between users' intentions and their actual behaviour is crucial for optimising the impact of the application on health-promoting activities.

This requires targeted improvements in functionality to ensure that the application aligns seamlessly with users' intentions and facilitates the desired health-promoting activities. Improvements to the user interface, feature optimization, and technical upgrades can ameliorate the differences between users' goals and their application of the application. Recognising and rectifying this disparity is vital for maximising the efficacy of the Living Cities application in promoting and sustaining wholesome habits amongst its users. “I haven't used it much lately. I only used the application at first, but then it was forgotten” (P9).

The lack of satisfactory incentives in the Living Cities application has emerged as a crucial factor leading to a decline in user motivation. Users have indicated a desire for more rewarding elements to improve their engagement and maintain involvement over an extended period. This highlights the vital role of incentives in shaping user conduct and encouraging ongoing participation.

To tackle this issue, a comprehensive review and optimization of the application's incentive structure is necessary. The incorporation of enticing rewards, the acknowledgement and celebration of user accomplishments, and the integration of varied motivational factors can vastly improve the application's user experience. By aligning these incentives with the users' personal preferences and aspirations, the Living Cities application can establish a stronger, more effective motivational base, leading to a higher level of engagement that is sustained over time. The integration of attractive incentives is significant in creating a positive and motivating atmosphere in the application, which encourages users to engage actively in health-promoting activities.

Participants reported minimal discernible alterations in their physical activity levels, implying that the application might not have had a ground-breaking influence on their pre-existing health habits. Such observations prompt a detailed scrutiny of the application's attributes and their correspondence with users' wellness aspirations.

“No, I chose to go for more runs, but in the end, I used the application for tasks I would have done anyway. Even if the application didn't exist” (P4).

Ultimately, the UTAUT2 framework has enabled a comprehensive evaluation of the Living Cities application's adoption and usage behaviour. This study expands on the theoretical understanding of technology adoption and offers practical insights for enhancing the functionality and features of the Living Cities application. Patterns and challenges discovered through the examination of usage behaviour have provided recommendations for optimizing the application's effectiveness in promoting health and well-being to users.

Building on the initial discoveries of the UTAUT2 model, user attitudes and incentives were further assessed via the Health Belief Model to gain a complete comprehension of an individual's perception of the complex link between physical activity and health, including the motivating factors and barriers that affect engagement. Through an in-depth understanding of the topic, this model presented valuable insights. The Health Belief Model, which centres on perceived severity, susceptibility, benefits, barriers, and cues to action, presented a more comprehensive examination of the psychological and perceptual factors that impact users' choices concerning physical activity in the Living Cities application.

In terms of perceived severity, the Participants consistently highlight the seriousness of health issues linked to a dearth of physical activity. This increased awareness among users highlighted a collective comprehension of the potential health implications that come from leading a sedentary lifestyle. The acknowledgement of gravity serves as an important motivator for encouraging users to prioritize physical activity.

Some participants reported feeling vulnerable to health problems, particularly as they aged, about their perceived susceptibility. This connection between insufficient physical activity and the potential for negative health outcomes emphasises the need for interventions tailored to specific age groups that address both concerns and motivations.

The majority of participants recognised the advantages linked to regular physical activity. This awareness demonstrates a comprehension of how participating in such actions enhances overall well-being. Utilising and reinforcing these perceived advantages can prove to be a potent driver for maintaining user engagement.

Perceived obstacles, such as a perceived shortage of time and motivation, surfaced as impactful hindrances that impede users' physical activity engagement. Recognising these obstacles is vital for implementing effective intervention approaches, enabling the formulation of tailored remedies that tackle users' particular difficulties concerning integrating physical activity into their routines.

External factors, such as guidance from health professionals and notifications from the application, have been found to play an important role in prompting individuals to take action and partake in physical activity. Specifically, notifications from the application would be an effective means of encouraging continued usage and participation, underscoring the importance of customized and timely reminders.

“And direct expectations that health will improve? I do not have any. Rather that it's just a certain incentive to do something” (P5).

“Quite helpful if you could somehow get a reminder or something” (P6).

An in-depth analysis of the likelihood of engaging in health-promoting behaviour revealed key determinants shaping participants' motivation and commitment to adopting healthier lifestyles.

The perceived severity of health problems played a significant role, as participants who thought health problems associated with inactivity were serious demonstrated a heightened motivation to engage in health-promoting behaviour. The link between perceived severity and motivation highlights the importance of individuals recognizing potential health risks. This emphasizes the necessity for health interventions to convey the seriousness of health issues objectively.

“I think if you don't move at all, there are major disadvantages” (P4).

Those who identified clear benefits in regular physical activity exhibited a greater inclination to engage in behaviour that promotes health. This correlation between perceived advantages and motivation has brought attention to positive reinforcement's function in inducing individuals to take up and maintain activities that promote health.

To conclude, the Health Belief Model analysis has enriched the comprehension of participants' outlooks on the complex interconnection between physical activity and health. The study highlighted the significance of acknowledging severity, comprehending individual susceptibility, and cultivating awareness of concrete advantages linked to health-enhancing actions. These observations furnish valuable details for enhancing interventions, like the Living Cities application, to correspond with users’ health attitudes and motivations more effectively.

4.5 Participants' Engagement with the Application

Investigating participant engagement with the Living Cities application uncovered various factors that underpin the diversity of ways individuals interact with the application.

Through examining use case scenarios, participants revealed a range of uses, showcasing the application's versatility in their daily lives. Notably, the engagement scenarios centred on outdoor activities, particularly walking and jogging. This emphasised the application's companion role in encouraging physical activity in the surrounding area and seamlessly integrating into users' daily routines.

The levels of engagement varied. The feedback emphasised the intrinsic variation in engagement levels among participants, as some participants effortlessly incorporated the application into their daily routines, while others reported it being less integrated into their activities. This variation offers valuable insights into the diverse user experiences and preferences within the participant cohort, thereby paving the way for bespoke interventions.

The participants highlighted the motivational features of the application, particularly noting the effectiveness of the points system and challenges as significant factors driving engagement. However, they reached a consensus that these motivational elements could be diversified to cater to a broader audience, ensuring inclusivity and catering to a wider range of user preferences. This would enhance sustained engagement.

A subgroup of participants experienced usability issues, particularly about the application's functionality. Obstacles in comprehending and employing specific features presented hindrances to engagement. This emphasises the importance of a user-friendly interface and intuitive design to encourage continued application usage. Overcoming these challenges is essential to optimise user experience.

Challenges integrated into the application were found to be effective in encouraging engagement, with participants actively engaging in both individual and collaborative challenges. However, recommendations were made to diversify the range of challenges to include a wider array of activities, promoting heightened interest and participation among users.

Community involvement is encouraged. The communal dimension of the engagement was notable, with participants valuing the collaborative features and interactions with local entities. However, there was a consensus in favour of extending community collaborations to involve a greater diversity of activities beyond fitness locations, to better correspond with various user interests and facilitate inclusivity.

Participants provided constructive feedback identifying areas for enhancing application engagement. Suggestions included diversifying activity options, refining the reward system, and ensuring a user-friendly and stable application interface. These valuable insights serve to optimize the application's features.

In summary, the engagement of participants with the Living Cities application exemplifies a vibrant interplay between usability, motivation, and community involvement. Establishing an appreciation for the multifaceted nature of user experiences and preferences is fundamental to enhancing the attributes of the application to foster sustained participation and contribute to the enhancement of the well-being and health of users.

4.6 Application Usage Patterns and Physical Activity Levels

The study of the intricate correlation between the usage patterns of the Living Cities application and the physical activity levels among participants has generated a range of findings. These provide an understanding of how individuals interacted with the application and its impact on their physical activity.

It was noted that there was variation in the frequency of application usage. Participants displayed varying levels of engagement with the application, with some integrating it seamlessly into their daily routines, while others opted to use it infrequently or sporadically due to personal preferences and daily schedules. These differences emphasise the need for personalised approaches to accommodate diverse user behaviours and activities.

The software served as a tool to track basic physical activities, like walking or running, according to user preferences. In contrast, the cycling facilities showed low usage rates, highlighting the diverse preferences among the participants, and suggesting areas where design improvements may be needed.

The reward mechanisms of the application, such as the points and challenges system, have been recognized as vital drivers for engagement, highlighting a strong correlation between these components and the willingness of individuals to take part in and sustain physical activities over an extended period. To devise effective approaches to improve user engagement, it is crucial to fully comprehend these motivating factors.

Participants participated in a variety of challenges offered by the application, demonstrating eagerness for individual and collaborative pursuits. However, user success levels in these challenges varied, highlighting diverse methods for achieving objectives and emphasizing the importance of flexible challenge formats that cater to all.

Whilst the application was effective in monitoring the behaviours of select users, it has been noted by participants that the overall influence on enhancing physical activity levels was restricted. Several users perceived the program as an addition to their already active lifestyle, whereas others viewed it as a mere

stimulus for occasional interaction, rather than a game-changing mechanism. This notion emphasises the critical relevance of aligning application features with the differing activity preferences of users.

The study revealed significant usability challenges with participants reporting difficulties specific to certain features and functions. These challenges negatively impacted engagement levels and had consequences for participants' physical activity routines. To enhance the user experience, it is essential to address these usability issues.

Participants have proposed enhancing the application's usage by improving the user interface, broadening the range of available activities, aligning better with individual preferences, and offering a more robust and user-friendly platform. These suggestions provide important insights for refining the application to better align with the needs and preferences of its users.

In conclusion, the interplay between application usage patterns and physical activity levels comprises a nuanced interweaving of user preferences, motivational drivers, and usability challenges. To enhance the Living Cities application and positively influence users' physical activity habits, it is crucial to comprehend these dynamics thoroughly.

4.7 Insights from UTAUT2 and HBM

Based on the model of Rongbin Yang et al. (2023) shown in Figure 3, the following results were obtained.

4.7.1 Perceived Benefits

The experiences of the users with the smart city application presented subtle indications of expected functioning, which subsequently affected their perceived advantages. The simplicity of usage became a vital aspect, and the process of instigating challenges became a hindrance. The users observed it to be burdensome, resulting in mixed emotions. Difficulties and confusion arose as hindrances to some users, while others view the application as instinctive. The interviews revealed a lack of awareness amongst users about the full range of the application's capabilities. The different user experiences and opinions on the application's usability highlight the complex relationship between performance expectations and perceived benefits. The challenges in adopting the application and varying user evaluations emphasise the significance of enhancing its usability to improve overall user contentment and maximise the perceived benefits of its characteristics.

4.7.2 Perceived Barriers

Effort expectancy and emotional motivation emerged as key influencing factors, shaping the barriers perceived by users of the smart city application. Participants reported significant challenges associated with effort expectancy, including the requirement to invest considerable time in comprehending the application's functionalities. Tracking within the application presented specific problems due to a lack of understanding, while complicated navigation further contributed to difficulties in interacting with the application. A significant obstacle to engagement was the lack of interest and relevance on an emotional level. Users reported that the application failed to create the desired emotional connection or meet their particular requirements. The role of negative emotions, notably frustration caused by technological difficulties, was crucial in this regard. This emotional pressure acted as a barrier, dampening users' enthusiasm for continued interaction with the application. The complex interplay of effort expectancy, emotional motivation and perceived impediments emphasises the necessity of efficient usability and amplified emotional connection to promote long-term user engagement.

4.7.3 Self-Efficacy

The present study examines the role of self-efficacy in smart city applications, taking into account factors such as habit, facilitating conditions, and social influence. The results show that there were no recognizable patterns of habit formation among participants in their interactions with the application. Regarding facilitating conditions, the majority of participants were able to utilize the application in question, with only two encountering difficulties. One participant voiced worry over the high battery consumption, indicating a technical limitation that affects facilitating circumstances. As for social influence, direct social influence proved insignificant, but the participants expressed wanting to compare their activities with friends or peers, signalling an inborn inclination for social benchmarks. The participants preferred that the application integrates features that make such comparisons possible. The complex interplay among habit, facilitating conditions, and social influence underscores the necessity of addressing technical limitations and incorporating social components to effectively enhance user engagement and self-efficacy.

4.7.4 Intentions to Use

The participants' intentions to embrace and apply the application displayed a complex interplay of several factors. A direct correlation was observed between users perceiving a considerable threat to their health and exhibiting a raised desire to employ the application as a proactive health initiative. This coincides with the recognition among many participants of a perceived threat to their general well-being, although viewpoints differed, with some individuals not regarding themselves as immediately vulnerable.

Users' intentions to engage with the application were shaped by their perceptions of threats, benefits, barriers and facilitators, as indicated by the factors above. Consequently, tailoring interventions to individual perspectives is crucial for successful adoption and continued use of health applications.

4.7.5 Cue to action

During the study, the Cue to Action was affected by the facilitation of conditions and social influence. Integrating social comparison features and resolving technical issues in the application's design could improve the cue to action, encouraging users to participate more actively. The prompt for participants to take action originated from health concerns or the desire to mitigate them, as opposed to social pressure or other external factors.

4.7.6 Actual Use

The adoption of the application by participants was shaped by multiple factors. The driving force behind this adoption was primarily the desire to address individual health concerns, rather than social influence. Although participants initially engaged with the application, persistent technological issues hindered their proactive approach.

Despite initially attempting to incorporate the application into their daily routines, participants faced various challenges as outlined earlier. The interplay of perceived benefits, barriers, and facilitating conditions, along with the impact of technical issues, collectively presented significant obstacles for integrating the application into their regular activities in a seamless manner. The integration of the application into their daily routine was hindered, indicating the complex dynamics that affect the use of healthcare applications.

4.8 Discussion of the Findings

A key finding that combines findings from UTAUT2 and the Health Belief Model is the critical role of perceived usability in encouraging increased physical activity in urban environments. Users showed a

strong inclination to engage with the smart city application if they found it easy to use and navigate. This is consistent with the UTAUT2 construct of 'effort expectancy', which emphasises the importance of users perceiving an application as easy to use.

In addition, the Health Belief Model suggests that individuals are more likely to adopt health-related behaviours if they perceive the recommended actions as easy to implement and understand. In the context of the smart city application, this means that users will be more likely to engage in physical activity if the application's interface and features are user-friendly.

Therefore, optimising the smart city application to improve usability can be a strategic intervention to promote increased physical activity, as it positively influences both the UTAUT2 and Health Belief Model dimensions.

4.8.1 Participants´ Engagement and Motivation

The Living Cities application elicited a range of responses from participants, showcasing their diverse perspectives. While some users found the gamification elements motivating and enjoyable, others encountered technical issues and usability concerns, resulting in hindrances to their overall engagement and motivation with the application.

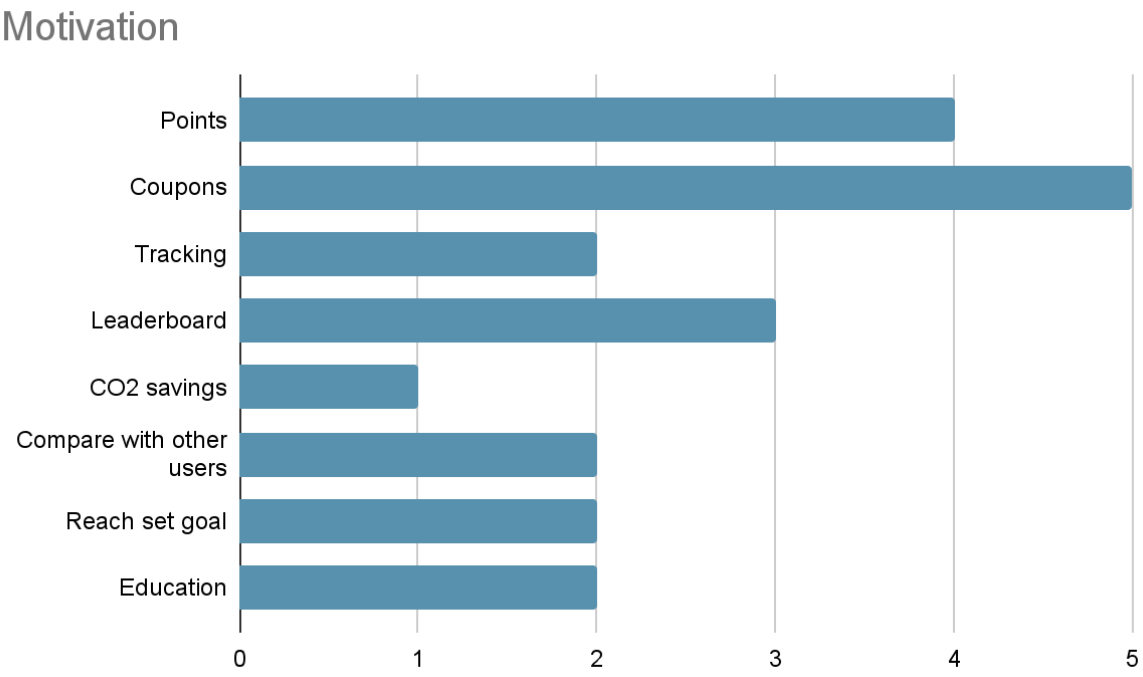
Users' positive feedback emphasised the attractiveness of incorporating gamification elements within the application. They found features such as the points system and challenges to be captivating, enhancing their physical activity routines. The intrinsic motivation resulting from these game-like components, complemented their overall experience, aligning with the application's primary objective of making health-promoting activities more appealing.

In contrast, a separate group of participants experienced obstacles associated with technical difficulties and usability issues. These challenges significantly affected their levels of motivation and engagement. The application's features encountered setbacks during navigation and technical disruptions, which hindered the smooth incorporation of the application into their daily lives. Consequently, these users faced obstacles that obstructed their ability to fully embrace and reap the rewards of the gamification components of the application.

Figure 7 depicts the prime reason behind the participants' application usage. It visually showcases the diverse factors influencing their engagement. The assorted feedback highlights the significance of addressing technical and usability issues to establish a consistent and constructive user experience. This feedback is valuable for improving the application's functionality and ensuring that it appeals to a wider audience by overcoming obstacles that hinder user motivation and engagement.

“Yes, but every now and then I tried to start and then I either got it right or not. I don't know, but it was there in my mind” (P8).

“It seemed to me to be incomplete and underdeveloped” (P3).



7 Motivations for use

The effect of gamification aspects, including challenges and rewards, was a prominent feature of the user feedback. Participants conveyed favourable views about these characteristics. Challenge points and Sparrow points were found to be captivating and efficacious in stimulating participants to engage in physical activities.

The implementation of Challenge points and Sparrow points in the gamified structure of the Living Cities application received favourable feedback from specific users. These points acted as concrete incentives, motivating individuals to undertake challenges and enhance their activity levels. The encouraging response to these gamification features indicates that they were pivotal in enhancing user engagement and participation in health-related activities.

The incorporation of challenges and rewards not only infused an enjoyable aspect to the application but also fostered a sense of achievement within its users. The acquisition of points by engaging in challenges and activities proved to be an incentive for some participants, resulting in a more engaging and stimulating experience. This affirmative outcome aligns with the overall objective of gamification in promoting user motivation and sustaining engagement in health-oriented attitudes.

Understanding the favourable reception of gamification elements permits strategic contemplation in future application developments. Employing the triumph of challenges and rewards whilst remedying possible impediments voiced by users, can refine the gamification strategy. This, therefore, may foster a more alluring and efficient approach towards encouraging physical activity and well-being among users.

“So as far as I understand it, the application is there to get physical exercise and then get discounts for activities in the area and you're always happy when you get discounts for things” (P4).

Technical issues, especially participant-reported glitches, added a challenging aspect to the user experience of the Living Cities application. One significant concern raised by users related to the challenge timer, as its incorrect functioning caused uncertainty when starting activities. The inconsistent timer functionality disrupted the application's intended flow, diminishing user motivation and overall engagement.

The challenges with the challenge timer highlight the need for seamless functionality to maintain user interest and encourage regular physical activity. Technical glitches can introduce frustration and uncertainty, affecting the application's effectiveness. Improving the application's usability is essential to provide users with a smoother and more dependable experience.

The significance of usability issues on user motivation cannot be overstated, as a reliable and user-friendly interface is critical to promoting positive interactions with the application. Valuable guidance for developers in refining the application's technical aspects can be obtained from participants' experiences with these challenges. By prioritising the resolution of usability issues, the Living Cities application can improve its overall effectiveness in advancing the health and well-being of its users.

Although integrated into the Living Cities application via collaborative challenges, community and collaboration did not elicit a strong response from participants. The level of engagement with community-related aspects and social features was not as anticipated. By and large, participants did not utilise these collaborative elements frequently, and their effectiveness in promoting sustained physical activity was not perceived as significant.

The insufficient uptake of community and collaboration functionalities implies that further measures and modifications may be required to boost their attractiveness and effectiveness. It is vital to investigate why users did not entirely adopt these characteristics and assess whether design changes or new elements can encourage greater involvement in the community.

Understanding the factors that contribute to the insufficient use of community-related features is essential for enhancing the Living Cities application. To tackle these issues, potential solutions might include re-evaluating the design of collaborative challenges, implementing new community-building functions, or exploring alternative ways to stimulate social interactions within the application. Improving the community aspect of the Living Cities application has the potential to foster a more connected and supportive environment. This, in turn, could lead to increased user engagement and ultimately promote healthier lifestyles.

Although some users appreciated the personalized challenges and insights offered by the Living Cities application, certain observations were made about its limitations. Some users found the tailored challenges to be somewhat restrictive, which hindered their engagement and reduced their participation in certain activities.

The feedback on customized challenges stresses the significance of presenting a broad spectrum of activities that match users' preferences and lifestyles. It implies that an adaptable and comprehensive approach to challenge design could increase user satisfaction and motivation. A more extensive range of activities, including those initially viewed as limiting, could lead to a more comprehensive and accommodating user experience.

Improving challenge diversity is essential to optimise user engagement. By enhancing the design and range of challenges, the Living Cities application can better accommodate the diverse preferences and activity levels of its users. This promotes continual engagement, leading to a livelier and healthier community in Ulm.

Analysis of participant feedback highlights the varying degrees of engagement with the Living Cities application, indicating significant differences in users' levels of involvement. Several factors contributed to this disparity, with technical issues, functional limitations, and divergent attitudes towards gamification emerging as key influencers.

Participants consistently reported technical issues, such as glitches and challenges with the application's functionality. These difficulties not only impacted the application's overall usability but also decreased motivation and impeded continued engagement. Variations in the application's performance caused uncertainty and, in some cases, users felt frustrated, which affected their inclination to participate actively.

Additionally, the gamified features, although engaging to some participants, were not universally well-received. The application's limited range of challenges and its apparent lack of diversity in activities restricted its appeal to a larger audience. Participants expressed a wish for more stimulating and different elements that would accommodate various preferences and promote sustained interaction.

In conclusion, the diverse engagement levels observed among participants can be attributed to a combination of technical difficulties, functional restrictions, and varying attitudes towards the gamified features. Addressing these issues is essential for optimising the user experience, improving motivation, and promoting increased and sustained engagement with the Living Cities application.

4.8.2 Impact on Physical Activity Levels:

Participants had mixed reactions to the impact of the application on their physical activity levels. Some reported an increase in activity as a result of using the application, while others didn't notice any significant changes in their routines. “I already go on many walks and do not use the application as a motivator. Although I do use the application, it is not the reason behind my walks” (P1).

Those who observed a positive impact cited the application's reminders and visual progress indicators, particularly the timer for various activities. They felt that these features motivated them to be more consistent in their physical activity.

Positive correlations were found between completing challenges and an increase in activity. Participants who successfully completed challenges, especially the partnered challenges, reported a slight increase in their physical activity levels.

However, technical issues such as inaccurate tracking or malfunctioning of certain features such as the distance tracking tool led to user dissatisfaction. This affected their ability to accurately measure their progress and therefore their motivation to maintain or increase physical activity.

Although the application aimed to promote community engagement, the collaborative challenges did not have a significant impact on users' physical activity levels. Users expressed minimal involvement in these collaborative features, limiting their impact on increasing physical activity.

In summary, the application had a mixed impact on users' physical activity levels. Whilst some users reported an increase in activity due to the motivational elements of the application, technical limitations and limited functionalities impacted the accurate measurement of activity and therefore the effectiveness of the application in influencing physical activity levels. In addition, the community aspects, although present, did not contribute significantly to increasing users' physical activity levels as expected.

4.8.3 Usability and Design Challenges:

Participants frequently encountered technical glitches and inconsistencies within the application, leading to frustration and a sub-optimal user experience. In particular, issues with the timer functionality and distance tracking affected the accuracy of activity measurement, and thus the perceived usability of the application.

Some users reported difficulty understanding certain features of the application, such as navigating between challenges, interpreting the scoring system, and the overall functionality of the application.

The issues identified, particularly the technical glitches and unintuitive design, had a negative impact on user engagement. Instances of glitches or inaccurate measurements led to decreased motivation and dissatisfaction among participants.

“To try it out for myself, for example, I already go for walks, but I never take my mobile phone with me. Yes, so it is not registered either. So that's a change for me, but otherwise, it can work” (P7).

Participants suggested several design improvements, such as a more intuitive and user-friendly interface, a reliable tracking system, and a clearer explanation of the scoring system. They emphasised the importance of these changes in improving the user experience and increasing engagement with the application.

In summary, there were significant challenges with the usability and design of the application, mainly due to technical issues and difficulties in understanding the user interface. These challenges had a significant impact on user engagement and motivation, highlighting the need for significant improvements to the functionality, reliability, and design clarity of the application to promote a more positive user experience.

4.8.4 Effectiveness of Gamification and Personalization:

Gamified challenges and scoring systems were found to be strong incentives for user participation. However, technical glitches, particularly in challenge tracking and point allocation, significantly affected the perceived effectiveness of these gamification elements.

Participants appreciated collaborative challenges with local entities but highlighted inconsistencies in challenge completion and corresponding point allocation. This inconsistency reduced the perceived effectiveness of collaborative challenges.

Users responded positively to the personalised insights provided by the application. However, the perceived effectiveness varied due to technical inaccuracies, such as inaccurate tracking of distances and activity times, which affected the reliability of the application's health recommendations.

“So, I tend to get the joy out of exercise. Maybe the application helps me to move more, but the application in general is more like icing on the cake” (P12).

Participants suggested a need for improving personalisation features and refining health insights to improve accuracy. Clearer, more tailored recommendations could positively impact user engagement and further encourage physical activity.

While the gamification elements provided motivation, their effectiveness was hampered by technical glitches. The personalisation features of the application showed potential but faced challenges in terms of accuracy and reliability, which affected their overall effectiveness.

In summary, while the gamification approach acted as a motivational driver, its effectiveness was significantly hampered by technical issues. Similarly, the personalised health insights showed promise, but inconsistencies and inaccuracies hampered their perceived effectiveness and required refinement to influence user engagement and physical activity levels more effectively.

4.8.5 Community and Social Interaction Aspects:

Participants showed interest in community collaboration and social engagement aspects of the application. However, limited opportunities for interactive community engagement within the application were identified as a barrier to effective use.

Collaborative challenges and interaction with local institutions were valued. However, more interactive community-based features were desired to foster a sense of community and shared goal achievement.

It was felt that enhancing the social aspect and building a more interactive community could encourage greater accountability and routine adherence. This in turn could have a positive impact on user engagement and long-term participation.

The lack of extensive social features, such as forums or interactive discussions, limited the perceived effectiveness of the application in promoting social interaction and community bonding.

Users suggested the inclusion of more interactive elements, community-based challenges, and discussion forums to increase social interaction. The lack of these elements affected the overall ability of the application to promote community bonding and support among users.

In summary, the community and social interaction aspects of the application were valued but limited, which affected their perceived effectiveness. The inclusion of more interactive, community-based features could potentially strengthen social interaction, accountability, and adherence to physical activity routines among users.

4.8.6 Addressing Demographic Differences:

Participants showed different levels of engagement depending on their age. Younger users were more receptive to gamified elements and social features, while older users showed a preference for personalised health insights and recommendations.

Gender differences were observed in application usage patterns. For example, men were more likely to engage in competitive challenges, while women tended to value the collaborative aspects and health insights.

The data suggests that moderating application features based on demographic factors is critical to optimising user engagement. Tailoring features to different age groups, genders and socio-economic statuses could significantly increase the effectiveness of the application.

Recognising the influence of demographics on user preferences and interactions within the application suggests the need for adaptive strategies. The application could benefit from flexible and customisable features that consider the different needs and preferences of users based on demographic differences.

In conclusion, the analysis highlighted the significant impact of demographics on user engagement. Tailoring the application's features to address these differences could significantly increase its effectiveness and appeal to different user groups.

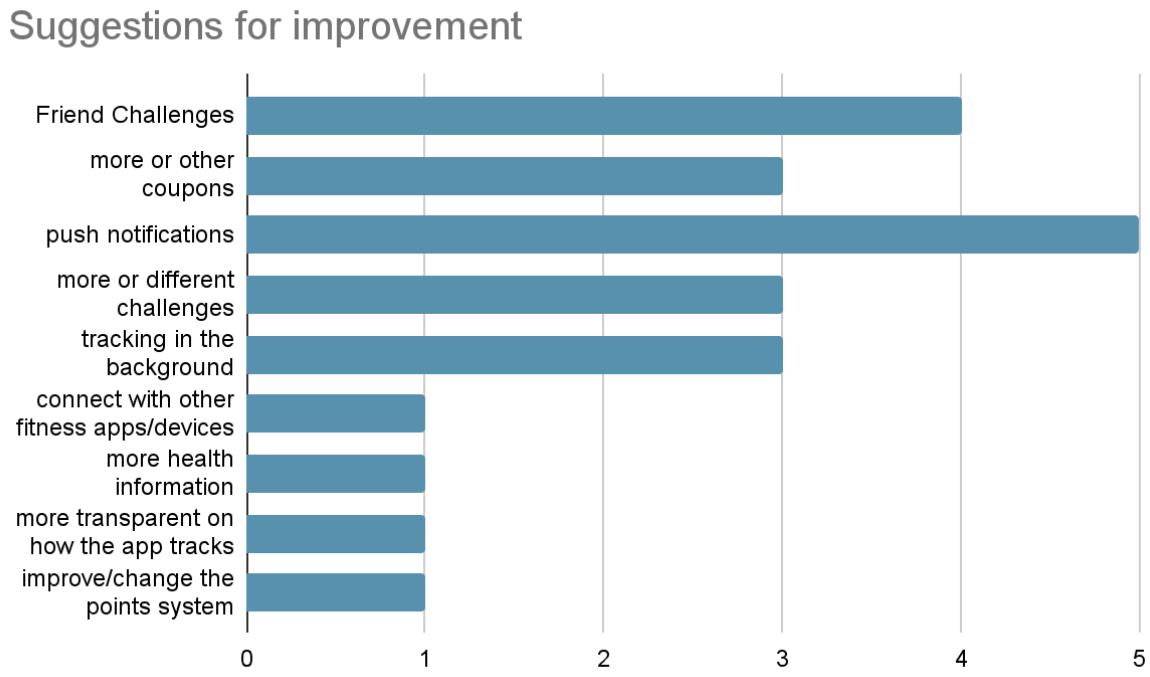
4.9 Desired Application changes

The participants' feedback indicated significant improvements. Despite the qualitative nature of this research, the qualitative data facilitated a nuanced examination of users' experiences and revealed recurring themes highlighting areas where participants experienced notable enhancements. Figure 8 thoughtfully presents these valuable insights, providing a visual representation of the key domains where users perceived positive changes.

Upon further analysis of the qualitative data, it was apparent that participants were content with particular features and functionalities. The user interface was particularly well-received, hailed as a fundamental aspect of a smoother and more enjoyable experience. This favourable opinion towards the user interface emphasises the importance of deliberate design choices in enhancing user engagement and satisfaction.

The qualitative analysis unveiled the upgraded performance of certain characteristics, as reported by users who experienced faster responses. This indicates a boosted overall responsiveness of the application, contributing to user satisfaction, as well as to the efficiency and seamlessness of the overall user experience. Furthermore, users noted improved navigation within the application, which significantly enhances user interactivity.

The user-generated feedback presents a range of positive experiences and improvements. The success of the implemented changes is highlighted by user satisfaction with the redesigned interface, improved feature performance, and seamless navigation. These qualitative findings not only validate the positive impact but also provide valuable direction for further refinements and enhancements in subsequent iterations of the application.



8 Desired improvements

Alongside these commendable results, participants passionately participated in presenting explicit proposals for prospective improvements. This active participation demonstrates the users' commitment to the application's enhancement and their willingness to contribute to it. Objective feedback gathered from respondents serves as a strategic blueprint for the subsequent iterative development of the application, providing concrete insights into users' preferred features and functionalities.

The dynamic feedback loop formed by the collaborative exchange between users and developers, as evidenced by the proposals submitted by the participants, enhances continuous improvement. By integrating user feedback into the developmental process, the application evolves in tandem with the users' changing needs and preferences. Essentially, this feedback mechanism driven by users guides the application towards a trajectory of sustainable growth and user satisfaction.

A recurring theme identified in the feedback from the participants was their wish for more captivating features that encourage amiable rivalry and collaboration. Several people expressed their excitement for tasks that not only test their limits but also encourage group participation in challenges with their peers. The prospect of collaborative endeavours and friendly rivalries sparked excitement, indicating a strong interest in social interactions within the application.

Furthermore, participants put forth the idea of an expanded coupon program as a means of further motivation. The suggestion involved offering additional coupons, specifically those redeemable for health-related items such as sports equipment. According to participants, this strategy could prove to be a highly effective motivator, offering tangible incentives that are aligned with their health and fitness objectives. The concept of earning vouchers for physical activity participation creates a sense of tangibility within the virtual environment, thereby bridging the gap between the digital and physical worlds to enhance the overall user experience.

A recurring request among study participants centred on their desire to receive push notifications for timely reminders and prompts to engage in health-promoting activities. Numerous participants highlighted the helpfulness of reminders in sustaining their commitment to physical activities. The integration of push notifications was perceived as a valuable feature for enhancing user engagement by maintaining health objectives at the forefront of their thoughts.

In addition, participants expressed a desire for greater diversity in the challenges presented by the application. A few participants perceived an absence of variety in the available challenges and hoped that a broader range of sports disciplines would be included. There was particularly keen interest in introducing challenges focused on muscle training, revealing the participants' inclination towards a more comprehensive and holistic approach to physical fitness. This feedback highlights the significance of addressing the varying interests and preferences of users, ensuring that the application aligns with a broad range of fitness objectives and physical pursuits.

The feedback provided by users highlights the necessity for improved dependability, precise monitoring capacities and enhanced motivation features. The incorporation of these improvements corresponds to user expectations, fostering continuous engagement.

“So, what I find a pity is that it only has the Donaubad inside, because I don't go to this bath. So, I can only use it actively for walking because I do not do other things. I do not have a bike, that doesn't really work. Jogging in and swimming at the moment, yes, but not in the Donaubad and, for example, if you then have healthy food here in the Glacis or shopping or beauty in the Glacis, that challenge doesn't work” (P1).

Participants highlighted the necessity for enhancing the usability of the application, stressing the significance of a user-friendly interface to ensure smooth interaction. Suggestions for improvements frequently included the desire for challenges to track progress automatically, without any need for manual activation, particularly concerning activities like walking. This efficient approach would improve user experience, by making it more convenient and intuitive for users to interact with the application.

In addition, users indicated a preference for integration with different health applications and devices, including smartwatches. This integration would provide a comprehensive view of their health and fitness data and would be in line with current trends in health technology, thus augmenting the overall functionality of the application.

Some participants suggested incorporating more comprehensive health information in the application to address physical inactivity risks. These recommendations reflect an increased awareness of health implications and the desire for the application to serve as an educational tool, promoting a deeper understanding of the consequences of sedentary behaviour.

For participants, it is crucial to have transparency in how the application tracks user activity. The participants emphasized the necessity of comprehending the technicalities underpinning the tracking procedure, which would establish trust and confidence in the application's capabilities. This transparency was

viewed as crucial to encourage user involvement and guarantee that users were adequately informed and empowered in their fitness endeavours.

Participants offered valuable feedback on the points system, providing nuanced suggestions to improve its effectiveness. A recurrent theme was to explore the possibility of awarding more points or introducing a points-per-minute system. This modification could lead to a more dynamic and adaptable points structure, acknowledging participants' efforts even if challenges are unfinished.

The input received from participants emphasises their enthusiasm for a points-based system that better aligns with the diverse range of physical activities and unique preferences. By implementing the suggested modifications, developers can better cater to a wider range of user expectations, thus fostering an increase in engagement and motivation from users. This ongoing cycle of feedback between users and developers is essential to the evolution of a health application that is user-friendly and effectively meets the diverse needs of its user base.

4.10 Optimizing User Engagement in Applications: Insights from Research Studies on the Efficacy of Trigger Messages

Another finding is that users require periodic reminders for effective application usage. Three participants forgot about the application almost instantly, and others provided feedback indicating they also needed reminders. This can be achieved using the concept of trigger messages. In the following, two studies are presented that examine the concept.

4.10.1 Study on Triggering: Impact of mHealth Application with Theory-Driven Messages

The investigation conducted by (Sittig et al. 2020) sought to evaluate the impact of a mHealth application that incorporates theory-driven trigger messages. The trigger messages, rooted in the Fogg Behaviour Model (FBM), were strategically designed to target self-efficacy, knowledge, and self-care. The study aimed to assess the feasibility and effectiveness of this approach through a pilot study involving individuals diagnosed with type 2 diabetes.

The pilot study involved two cohorts, each consisting of twenty patients with type 2 diabetes, recruited as employees from within a healthcare system. Employing a within-subjects design, participants interacted with the capABILITY application and received or did not receive text messages in alternate blocks. Trigger messages, including spark and facilitator messages, were crafted based on social cognitive theory (SCT), FBM, and persuasive technology.

Pre- and post-intervention assessments demonstrated statistical significance on three out of the seven health survey measures, specifically related to general diet, exercise, and blood glucose. Further analysis of high and mid users of capABILITY revealed a significant difference in both self-efficacy and exercise. While the repeated-measures analysis of variance (ANOVA) did not identify statistically significant differences across groups, there was a notable trend among spark conditions, indicating quicker responses post-message receipt.

4.10.2 Study on Push Notifications: Impact on Body Composition in Overweight Women

In the contemporary era, the advent of technology, particularly mobile Internet access, has substantially influenced daily life behaviours. Recent studies have delved into the efficacy of health-related actions via mobile phones, with a specific focus on push notifications.

The clinical trial conducted by (Hernández-Reyes et al. 2020) aimed to rigorously evaluate the efficacy of push notifications in enhancing the body composition of overweight or obese adult women. The intervention centred around a dietary procedure, and the primary objective was to meticulously analyse the

evolution of body composition based on the integration of push notifications and prescribed physical activity.

The study employed a robust two-arm randomized controlled trial involving 117 adult obese women. Participants attended face-to-face consultations once a week for a duration of 6 months, utilizing a designated application and a provided pedometer. The control group lacked access to self-monitoring functionalities for weight, gamification features, or prescribed physical activity. In contrast, the intervention group had exclusive access to specific application functionalities and push notifications, aiming to encourage compliance with both dietary guidelines and physical activity.

The receipt of push notifications during the intervention yielded a significant increase in body fat loss within the intervention group compared to the control group. Notably, push notifications demonstrated efficacy in maintaining muscle mass, showcasing a significant difference between the intervention and control groups. Despite these variations, the overall weight loss did not exhibit a significant difference between the two groups.

4.10.3 Conclusions

The findings of the first study suggest that the theory-driven mHealth application is a viable means of enhancing self-efficacy and promoting health-related behaviours. Despite the limited sample size, spark triggers exhibited the potential to stimulate engagement in mobile tools, exemplified by increased capABILITY usage based on spark timing. This study advocates for the adoption of theory-driven personalization in mobile tools as an effective form of intervention.

The second study's findings underscore the effectiveness of push notifications in a comprehensive weight loss program, manifesting in a considerable reduction in fat mass and the preservation or augmentation of muscle mass. Particularly noteworthy is the effectiveness of push notifications among participants engaged in intense physical activity programs. As future interventions are considered, it is recommended to extend the evaluation period and explore the nuanced impact of varying message contents, delivery times, and frequency.

4.11 Comparison with Hypotheses

Hypothesis 1:

The research supports the initial hypothesis, revealing convincing evidence of a favourable association between integrating gamification features into smart urban applications and people's propensity to participate in physical activities. The investigation highlights that applications that integrate challenges, rewards, and competition through gamification methods are linked to increased levels of motivation among users, exceeding the engagement detected in applications that do not have these elements.

The integration of challenges into smart city applications has emerged as a powerful incentive. Users display a preference for establishing and accomplishing challenges, transforming their physical activities into goal-oriented endeavours. Challenges offer a structured framework for users to work towards and also generate a sense of satisfaction upon completion. This feeling of achievement plays an important role in fostering long-term motivation for physical activity.

Another critical aspect of gamification is rewards, which have a significant impact on the user's behaviour. The expectation of rewards serves as an internal motivator, prompting users to surpass their performance metrics and compete with themselves. The research shows that applications that offer tangible or virtual rewards, such as points, badges, or discounts, are more effective in sustaining the user's interest and commitment to physical activities.

Introducing competition through gamification elevates the social aspect of users' exercise regimes. The research indicates that including competitive features, such as leader boards or challenges with fellow users, cultivates a feeling of connectedness and responsibility among participants. The urge to excel over others or cooperate towards shared objectives augments the motivational influence of smart city applications.

Hypothesis 2:

The study's findings unequivocally bolster the second hypothesis, highlighting that smart city applications that offer features such as activity tracking, goal setting and health insights have a greater impact on user exercise routines than applications that provide generic content. The data analysis exhibits a substantial correlation between the integration of such features and increased user involvement in physical activities.

The integration of activity tracking has emerged as a key factor in enabling users to monitor and assess their exercise habits. This self-awareness promotes a proactive attitude towards health, as individuals become more aware of their physical activities and are motivated to attain their designated targets. Emphasis is placed on the relevance of goal setting, manifested in the marked escalation in user dedication when endeavouring to surpass pre-defined objectives. The incorporation of gamification enhances the user experience by converting exercise into a goal-oriented and rewarding activity.

In addition, the provision of individualized health statistics and information on the dangers of a sedentary lifestyle serves as an educational resource. Users have expressed a desire for greater insight into their health, and applications that offer these features promote a more informed user base. This knowledge, in turn, influences behaviour, guiding users towards healthier lifestyle choices.

The study confirms that generic content, which merely provides basic information, lacks interactive and personalised elements that encourage sustained user engagement. The implications of these findings extend beyond the domain of application design and delve into the realm of public health strategies within urban environments. As smart city applications develop into key components of health interventions, the study demonstrates the effectiveness of features in encouraging enduring modifications in exercise behaviours among users.

Hypothesis 3:

The results of the study deviate from the initial hypothesis and do not show a substantiated positive correlation between the use of smart city applications and an increase in physical activity levels. The data collected throughout the study does not show a significant relationship between active engagement with the application's features such as tracking activities, setting goals and participating in challenges and an observable increase in users' physical activity. Despite users actively using these features, there was no discernible improvement in their physical activity levels. In contrast to the expected results, participants who expressed active engagement did not report increased adherence to exercise routines. This incongruence challenges the theoretical underpinnings of the hypothesis and highlights the importance of user interaction in promoting favourable behavioural change. Consequently, the results of the study highlight the need for a nuanced approach, suggesting that the interactive facet of smart city applications may not be universally correlated with increased physical activity levels, as perceived improvements were not reflected in users' reported fitness levels.

Hypothesis 4:

The research findings do not provide strong support for the hypothesis that smart city applications that promote social interaction and collaboration will significantly contribute to increasing adherence to phys-

ical activity routines. Despite the theoretical basis emphasising the importance of social factors in cultivating sustainable exercise habits, participants in the study reported minimal social impact during the test phase. The intended social competition features, such as the leader board, did not effectively create a sense of community or shared goal achievement as expected. While participants engaged with the application individually, the expected social influence on their commitment to exercise routines did not manifest as strongly as hypothesised. This nuanced finding suggests that, in the specific context of the study, the social elements embedded in the smart city application may not have had the expected impact on users' commitment to regular physical activity.

Hypothesis 5:

The study findings corroborate the hypothesis that user demographics, including age, gender, and socio-economic status, could moderate the relationship between smart city applications and physical activity participation. The analysis identified subtle variations in the efficacy of the application features among varied demographic cohorts. Younger users were found to be more responsive to gamification elements, while older users preferred straightforward health insights without complexity. However, there were no notable gender differences in levels of social engagement. There were also no differences in terms of other demographics.

5 Discussion

5.1 Theoretical Contribution

The investigation into user perceptions and engagement with the Living Cities application, supported by the UTAUT2, offers significant insight into ongoing discussions on technology acceptance models.

Aligning with previous literature (Yuan et al. 2015), the results confirm the notable influence of hedonic motivation on technology acceptance within the UTAUT framework. Participants in the research identified the enjoyment factor as a crucial element influencing their motivation to engage with the Living Cities application. This finding is consistent with previous studies that highlight the significance of hedonic factors in predicting and comprehending user acceptance.

The utilization of the application and its health implications were also considered. Contrary to previous research indicating that mobile applications may impact health results (Flores Mateo et al. 2015), the analysis of the Living Cities application suggests a more complex relationship. While participants recognized the potential for the application to encourage physical activity, they reported limited effects on overall health habits. This nuanced discovery urges a rethinking of direct health implications associated with mobile applications, underlining the requirement for customized interventions to optimize health outcomes.

The research concurs with prior studies that pinpoint gamification elements' impactful role in enhancing user involvement (Lister et al. 2014). The reward system within the Living Cities application, a prominent gamification feature, received positive feedback from participants, suggesting its efficacy in encouraging and maintaining user engagement. This discovery highlights the value of integrating gamified components to amplify user motivation and target attainment in health-related applications.

In summary, the study enhances the theoretical landscape by reinforcing the significance of hedonic motivation within the UTAUT framework, delivering detailed insights into the health implications of mobile applications, and acknowledging the affirmative effect of gamification elements, especially reward systems, on user engagement. These findings contribute to the continual development and progression of theoretical frameworks, highlighting the significance of comprehensively comprehending user motivations and expectations concerning the acceptance of technology.

5.2 Implications for Practice

The findings obtained from users' experiences with the Living Cities application yield practicable suggestions for enhancing its functionality and usability. The recommendations are based on the UTAUT framework, health-related factors, and the gamification features that emerged from the study.

To adhere to UTAUT guidelines, professionals should place emphasis on enhancing the transparency and accessibility of the application's tracking features. By openly communicating the application's monitoring and recording processes, user confidence and satisfaction can be bolstered. Moreover, rectifying any technical problems that compromise the application's reliability is imperative for retaining user engagement. Regular updates and maintenance to troubleshoot glitches are fundamental in creating a favourable user experience.

Practical improvements can be made by implementing successful push notifications. To significantly boost engagement, notifications must be timely, personalised, and relevant to individual user preferences. By integrating successful mHealth intervention elements, practitioners can use push notifications as valuable cues for stimulating consistent application usage.

Healthcare professionals seeking to maximize the application's impact on health should contemplate enabling background activity tracking. This improvement guarantees a holistic and precise depiction of users' physical activities, capturing subtleties that may go unnoticed during foreground tracking. Furthermore, broadening the selection of monitored exercises, including weightlifting and home fitness routines, caters to diverse user preferences whilst endorsing inclusivity, aligning with wider health and fitness goals.

Quests, Reworked Points System, and Social Challenges to enhance gamification elements, practitioners can introduce quests to motivate users for sustained engagement. Personalised challenges that align with individual fitness goals could be offered through these quests. Reworking the points system to provide more meaningful rewards and incentives could further enhance user motivation. Introducing challenges among application users fosters a sense of community engagement, promoting social interactions. This not only contributes to sustained application engagement but also aligns with the communal aspects that were appreciated by study participants.

In conclusion, the findings emphasise the significance of user-centric enhancements, technological reliability, health-focused features, and gamification refinements for the practice. By addressing key areas, practitioners can optimize the Living Cities application strategically. This involves aligning it closely with user expectations, promoting sustained engagement, and ultimately improving health and well-being.

5.3 Limitations and Further Research

The present study only examines certain gamification components. To improve our understanding of this subject, future research should examine other gamification methodologies. Experimenting with a variety of motivational approaches, reward systems, and gaming elements may uncover more efficient methods to improve user engagement and promote consistent application usage.

The investigation specifically centred on temporary user experiences and did not deliver an all-inclusive evaluation of long-standing health results. In the future, research should involve longitudinal studies to evaluate the sustained impact of smart city healthcare applications on users' health. An assessment of long-term, sustainable changes in behaviour and health improvements would provide a thorough comprehension of the applications' potential in facilitating enduring positive health results.

Advances in technology offer opportunities for the development of health applications. Future research could investigate advanced technology integration, such as AI-driven personalisation, virtual reality (VR) features, and wearables, and their impact on user experience, engagement, and overall effectiveness. This analysis could contribute to the ongoing development of health-promoting applications within the smart city framework.

In conclusion, the identification of the present study's limitations presents opportunities for forthcoming investigations to enrich our understanding and improve health applications in smart cities. Researching alternative gamification strategies, assessing long-term health effects, and incorporating innovative technologies are all encouraging paths for practitioners and scholars striving to enhance the effectiveness of health-supporting applications in smart city environments.

6 Conclusion

Upon traversing the intricate intersection of technology, urban dynamics, and health, this exploration of smart city applications concludes with a tapestry of insights. The symbiotic relationship between urban environments and human health has undergone scrutiny, highlighting the role of smart city applications in reshaping this dynamic.

From the outset of recognising urban physical inactivity as a health concern to conceptualising smart city applications as interventions, this thesis has followed a trajectory of posing questions, extracting findings, and proposing avenues for future exploration.

The enhancement of smart city applications to promote physical activity necessitates a design ethos centred on the user. As revealed by this thesis, the incorporation of gamification in these applications serves as a guiding light, transforming the pursuit of health into a captivating and delightful endeavour. Key findings underscore the significance of gamification elements, particularly the reward system, in enhancing user engagement. The study also revealed that enjoyment is a significant motivating factor for the participants to engage with the Living Cities application.

These applications have promised to not only reduce sedentary behaviour but also promote healthier urban lifestyles. The perspective on urban health challenges has changed, with the increasing role of smart city applications as dynamic tools. Through an examination of their impact on health outcomes, it has been found that both the advancements achieved thus far and the diverse areas that are still unexplored.

The study has scrutinized the psychological intricacies regarding users' perceptions of health benefits and barriers. It has provided an in-depth comprehension of the complex interplay between individual motivations and technology. Contrary to previous research findings, this study proposes a nuanced correlation between mobile applications, specifically the Living Cities application, and individuals' overall health habits.

The study confirms that smart city applications surpass mere technological advancements and instead serve as vital elements of a strategic approach towards responding to the constantly evolving health scenario in present-day urban areas. Practical suggestions arise, prioritising transparency and ease of access in tracking tools, prompt resolution of technical issues, and successful push notification implementation.

The Living Cities application, which focuses on environmental awareness and incorporates gamification features, serves as an illustrative example. Not only does it promote individual health, but it also encourages a wider ecological perspective, prompting users to consider the interdependence of their actions with the environment. The future seems to be a realm where technology, human behaviour, and urban well-being intersect in exceptional ways, paving the way for more vibrant, connected, and healthier cities.

Statutory Declaration

I hereby confirm that the attached bachelor thesis is my own work and that it has not been used for other examination purposes; I have named all the sources and auxiliary material used, and I have marked appropriately quotations used verbatim or which I have given the gist of.

89231 Neu-Ulm, 27.11.2023

Place, Date

Signature

References

Ahmad, N. A., Mat Ludin, A. F., Shahar, S., Mohd Noah, S. A., and Mohd Tohit, N. 2022. “Willingness, perceived barriers and motivators in adopting mobile applications for health-related interventions among older adults: a scoping review,” *BMJ Open* (12:3), e054561 (doi: 10.1136/bmjopen-2021-054561).

Alharbi, N. S., AlGhanmi, A. S., and Fahlevi, M. 2022. “Adoption of Health Mobile Apps during the COVID-19 Lockdown: A Health Belief Model Approach,” *International Journal of Environmental Research and Public Health* (19:7), p. 4179 (doi: 10.3390/ijerph19074179).

Baretta, D., Perski, O., and Steca, P. 2019. “Exploring Users' Experiences of the Uptake and Adoption of Physical Activity Apps: Longitudinal Qualitative Study,” *JMIR mHealth and uHealth* (7:2), e11636 (doi: 10.2196/11636).

Bender, M. S., Choi, J., Arai, S., Paul, S. M., Gonzalez, P., and Fukuoka, Y. 2014. “Digital technology ownership, usage, and factors predicting downloading health apps among caucasian, filipino, korean, and latino americans: the digital link to health survey,” *JMIR mHealth and uHealth* (2:4), e43 (doi: 10.2196/mhealth.3710).

Birkhoff, S. D., and Smeltzer, S. C. 2017. “Perceptions of Smartphone User-Centered Mobile Health Tracking Apps Across Various Chronic Illness Populations: An Integrative Review,” *Journal of Nursing Scholarship* (49:4), pp. 371-378 (doi: 10.1111/jnu.12298).

C.C., S., and Prathap, S. K. 2020. “Continuance adoption of mobile-based payments in Covid-19 context: an integrated framework of health belief model and expectation confirmation model,” *International Journal of Pervasive Computing and Communications* (16:4), pp. 351-369 (doi: 10.1108/IJPCC-06-2020-0069).

Chang, A. 2012. “UTAUT and UTAUT 2: A Review and Agenda for Future Research,” *The Winners* (13:2), p. 10 (doi: 10.21512/tw.v13i2.656).

Deterding, S., Dixon, D., Khaled, R., and Nacke, L. 2011. “From game design elements to gamefulness,” in *Proceedings of the 15th International Academic MindTrek Conference Envisioning Future Media Environments*, A. Lugmayr, H. Franssila, C. Safran and I. Hammouda (eds.), Tampere Finland. 28 09 2011 30 09 2011, New York, NY: ACM, pp. 9-15 (doi: 10.1145/2181037.2181040).

Edwards, E. A., Lumsden, J., Rivas, C., Steed, L., Edwards, L. A., Thiyagarajan, A., Sohanpal, R., Caton, H., Griffiths, C. J., Munafò, M. R., Taylor, S., and Walton, R. T. 2016. “Gamification for health promotion: systematic review of behaviour change techniques in smartphone apps,” *BMJ Open* (6:10), e012447 (doi: 10.1136/bmjopen-2016-012447).

Eisenstadt, M., Liverpool, S., Infanti, E., Ciuvat, R. M., and Carlsson, C. 2021. “Mobile Apps That Promote Emotion Regulation, Positive Mental Health, and Well-being in the General Population: Systematic Review and Meta-analysis,” *JMIR mental health* (8:11), e31170 (doi: 10.2196/31170).

Ek, A., Alexandrou, C., Delisle Nyström, C., Direito, A., Eriksson, U., Hammar, U., Henriksson, P., Maddison, R., Trolle Lagerros, Y., and Löf, M. 2018. “The Smart City Active Mobile Phone Intervention (SCAMPI) study to promote physical activity through active transportation in healthy adults: a study protocol for a randomised controlled trial,” *BMC Public Health* (18:1), p. 880 (doi: 10.1186/s12889-018-5658-4).

Eremia, M., Toma, L., and Sanduleac, M. 2017. “The Smart City Concept in the 21st Century,” *Procedia Engineering* (181), pp. 12-19 (doi: 10.1016/j.proeng.2017.02.357).

Fanning, J., Mullen, S. P., and McAuley, E. 2012. “Increasing physical activity with mobile devices: a meta-analysis,” *Journal of Medical Internet Research* (14:6), e161 (doi: 10.2196/jmir.2171).

Ferguson, C., Davidson, P. M., Scott, P. J., Jackson, D., and Hickman, L. D. 2015. “Augmented reality, virtual reality and gaming: an integral part of nursing,” *Contemporary Nurse* (51:1), pp. 1-4 (doi: 10.1080/10376178.2015.1130360).

Flaherty, S.-J., McCarthy, M., Collins, A., and McAuliffe, F. 2018. “Can existing mobile apps support healthier food purchasing behaviour? Content analysis of nutrition content, behaviour change theory and user quality integration,” *Public Health Nutrition* (21:2), pp. 288-298 (doi: 10.1017/s1368980017002889).

Flores Mateo, G., Granado-Font, E., Ferré-Grau, C., and Montaña-Carreras, X. 2015. “Mobile Phone Apps to Promote Weight Loss and Increase Physical Activity: A Systematic Review and Meta-Analysis,” *Journal of Medical Internet Research* (17:11), e253 (doi: 10.2196/jmir.4836).

Gabriele, J. M., Carpenter, B. D., Tate, D. F., and Fisher, E. B. 2011. “Directive and nondirective e-coach support for weight loss in overweight adults,” *Annals of behavioral medicine : a publication of the Society of Behavioral Medicine* (41:2), pp. 252-263 (doi: 10.1007/s12160-010-9240-2).

Garavand, A., Samadbeik, M., Nadri, H., Rahimi, B., and Asadi, H. 2019. “Effective Factors in Adoption of Mobile Health Applications between Medical Sciences Students Using the UTAUT Model,” *Methods of Information in Medicine* (58:4-05), pp. 131-139 (doi: 10.1055/s-0040-1701607).

Gay, V., and Leijdekkers, P. 2015. “Bringing Health and Fitness Data Together for Connected Health Care: Mobile Apps as Enablers of Interoperability,” *Journal of Medical Internet Research* (17:11), e260 (doi: 10.2196/jmir.5094).

Gibbs, G. R., Friese, S., and Mangabeira, W. C. 2002. “The Use of New Technology in Qualitative Research. Introduction to Issue 3(2) of FQS,” *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research* (3:2) (doi: 10.17169/fqs-3.2.847).

Griebel, L., Hinderer, M., Amr, A., Meder, B., Schweig, M., Deuber, D., Egger, C., Kawohl, C., Kr&#228, mer, A., Flade, I., Schr&#246, der, D., and Prokosch, H.-U. 2020. “The Patient as Genomic Data Manager – Evaluation of the PROMISE App,” in *Digital Personalized Health and Medicine*, IOS Press, pp. 1061-1065 (doi: 10.3233/SHTI200324).

Hernández-Reyes, A., Cámara-Martos, F., Molina Recio, G., Molina-Luque, R., Romero-Saldaña, M., and Moreno Rojas, R. 2020. “Push Notifications From a Mobile App to Improve the Body Composition of Overweight or Obese Women: Randomized Controlled Trial,” *JMIR mHealth and uHealth* (8:2), e13747 (doi: 10.2196/13747).

Hong, J. S., Wasden, C., and Han, D. H. 2021. “Introduction of digital therapeutics,” *Computer Methods and Programs in Biomedicine* (209), p. 106319 (doi: 10.1016/j.cmpb.2021.106319).

Hsieh, P.-J. 2023. “The impact of motivations, health beliefs, and basic human needs on mobile self-management: an extension of the self-determination theory perspective,” *Behaviour & Information Technology* (42:8), pp. 1045-1063 (doi: 10.1080/0144929X.2022.2059007).

J. Degenhard. 2023. “Number of smartphone users worldwide 2013-2028,” available at https://www.statista.com/forecasts/1143723/smartphone-users-in-the-world, accessed on Nov 15 2023.

Jim Hughes, and Steven Jones. 2003. *Reflections on the Use of Grounded Theory in Interpretive Information Systems Research*.

Jones, M., Morris, J., and Deruyter, F. 2018. “Mobile Healthcare and People with Disabilities: Current State and Future Needs,” *International Journal of Environmental Research and Public Health* (15:3), p. 515 (doi: 10.3390/ijerph15030515).

Lincoln C. Wood, and Torsten Reiners. “Gamification,” in *Encyclopedia of Information Science and Technology, Third Edition*, IGI Global, pp. 3039-3047 (doi: 10.4018/978-1-4666-5888-2.ch297).

Lister, C., West, J. H., Cannon, B., Sax, T., and Brodegard, D. 2014. “Just a fad? Gamification in health and fitness apps,” *JMIR serious games* (2:2), e9 (doi: 10.2196/games.3413).

Litman, L., Rosen, Z., Spierer, D., Weinberger-Litman, S., Goldschein, A., and Robinson, J. 2015. “Mobile Exercise Apps and Increased Leisure Time Exercise Activity: A Moderated Mediation Analysis of the Role of Self-Efficacy and Barriers,” *Journal of Medical Internet Research* (17:8), e195 (doi: 10.2196/jmir.4142).

Mackey, A., and Gass, S. M. (eds.). 2012. *Research methods in second language acquisition*: *A practical guide*, Chichester: Wiley-Blackwell.

Mayer, G., Gronewold, N., Alvarez, S., Bruns, B., Hilbel, T., and Schultz, J.-H. 2019. “Acceptance and Expectations of Medical Experts, Students, and Patients Toward Electronic Mental Health Apps: Cross-Sectional Quantitative and Qualitative Survey Study,” *JMIR mental health* (6:11), e14018 (doi: 10.2196/14018).

Melzner, J., Heinze, J., and Fritsch, T. 2014. “Mobile Health Applications in Workplace Health Promotion: An Integrated Conceptual Adoption Framework,” *2212-0173* (16), pp. 1374-1382 (doi: 10.1016/j.protcy.2014.10.155).

Mendiola, M. F., Kalnicki, M., and Lindenauer, S. 2015. “Valuable features in mobile health apps for patients and consumers: content analysis of apps and user ratings,” *JMIR mHealth and uHealth* (3:2), e40 (doi: 10.2196/mhealth.4283).

Milne-Ives, M., Lam, C., Cock, C. de, van Velthoven, M. H., and Meinert, E. 2020. “Mobile Apps for Health Behavior Change in Physical Activity, Diet, Drug and Alcohol Use, and Mental Health: Systematic Review,” *JMIR mHealth and uHealth* (8:3), e17046 (doi: 10.2196/17046).

Montgomery, R. M., Boucher, E. M., Honomichl, R. D., Powell, T. A., Guyton, S. L., Bernecker, S. L., Stoeckl, S. E., and Parks, A. C. 2021. “The Effects of a Digital Mental Health Intervention in Adults With Cardiovascular Disease Risk Factors: Analysis of Real-World User Data,” *JMIR Cardio* (5:2), e32351 (doi: 10.2196/32351).

Mosa, A. S. M., Yoo, I., and Sheets, L. 2012. “A systematic review of healthcare applications for smartphones,” *BMC Medical Informatics and Decision Making* (12:1), p. 67 (doi: 10.1186/1472-6947-12-67).

Müller, A. M., Maher, C. A., Vandelanotte, C., Hingle, M., Middelweerd, A., Lopez, M. L., DeSmet, A., Short, C. E., Nathan, N., Hutchesson, M. J., Poppe, L., Woods, C. B., Williams, S. L., and Wark, P. A. 2018. “Physical Activity, Sedentary Behavior, and Diet-Related eHealth and mHealth Research: Bibliometric Analysis,” *Journal of Medical Internet Research* (20:4), e122 (doi: 10.2196/jmir.8954).

O'Brien, H. L., Morton, E., Kampen, A., Barnes, S. J., and Michalak, E. E. 2020. “Beyond clicks and downloads: a call for a more comprehensive approach to measuring mobile-health app engagement,” *BJPsych Open* (6:5), e86 (doi: 10.1192/bjo.2020.72).

Rabin, C., and Bock, B. 2011. “Desired features of smartphone applications promoting physical activity,” *Telemedicine journal and e-health : the official journal of the American Telemedicine Association* (17:10), pp. 801-803 (doi: 10.1089/tmj.2011.0055).

Ramos, G., Ponting, C., Labao, J. P., and Sobowale, K. 2021. “Considerations of diversity, equity, and inclusion in mental health apps: A scoping review of evaluation frameworks,” *Behaviour research and therapy* (147), p. 103990 (doi: 10.1016/j.brat.2021.103990).

Riley, W. T., Rivera, D. E., Atienza, A. A., Nilsen, W., Allison, S. M., and Mermelstein, R. 2011. “Health behavior models in the age of mobile interventions: are our theories up to the task?” *Translational behavioral medicine* (1:1), pp. 53-71 (doi: 10.1007/s13142-011-0021-7).

Rocha, P., Dias, Santinha, Rodrigues, and Queirós. 2019. “Smart Cities and Healthcare: A Systematic Review,” *Technologies* (7:3), p. 58 (doi: 10.3390/technologies7030058).

Romeo, A., Edney, S., Plotnikoff, R., Curtis, R., Ryan, J., Sanders, I., Crozier, A., and Maher, C. 2019. “Can Smartphone Apps Increase Physical Activity? Systematic Review and Meta-Analysis,” *Journal of Medical Internet Research* (21:3), e12053 (doi: 10.2196/12053).

Rongbin Yang, Santoso Wibowo, and Sameera Mubarak. 2023. *An Investigation into Domestic Violence Victims' Adoption of Chatbots for Help-seeking: Based on the UTAUT2 and Health Belief Models*.

Sallis, J. F., and Saelens, B. E. 2000. “Assessment of physical activity by self-report: status, limitations, and future directions,” *Research Quarterly for Exercise and Sport* (71 Suppl 2), pp. 1-14 (doi: 10.1080/02701367.2000.11082780).

Samuel Attuquayefio, and Hilla Addo. 2014. “REVIEW OF STUDIES WITH UTAUT AS CONCEPTUAL FRAMEWORK,” *European Scientific Journal* (10:8), pp. 1857-7881.

Sittig, S., Wang, J., Iyengar, S., Myneni, S., and Franklin, A. 2020. “Incorporating Behavioral Trigger Messages Into a Mobile Health App for Chronic Disease Management: Randomized Clinical Feasibility Trial in Diabetes,” *JMIR mHealth and uHealth* (8:3), e15927 (doi: 10.2196/15927).

Sucasas, V., Mantas, G., Radwan, A., and Rodriguez, J. 2016. “An OAuth2-based protocol with strong user privacy preservation for smart city mobile e-Health apps,” in *2016 IEEE International Conference on Communications (ICC)*, IEEE (doi: 10.1109/icc.2016.7511598).

Susan A. Brown, and Viswanath Venkatesh. 2005. *A model of adoption of technology in the household: A baseline model test and extension incorporating household life cycle*.

Venkatesh, Thong, and Xu. 2012. “Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology,” *MIS Quarterly* (36:1), p. 157 (doi: 10.2307/41410412).

Weinstein, R. S., Lopez, A. M., Joseph, B. A., Erps, K. A., Holcomb, M., Barker, G. P., and Krupinski, E. A. 2014. “Telemedicine, telehealth, and mobile health applications that work: opportunities and barriers,” *The American Journal of Medicine* (127:3), pp. 183-187 (doi: 10.1016/j.amjmed.2013.09.032).

Wildenbos, G. A., Peute, L., and Jaspers, M. 2018. “Aging barriers influencing mobile health usability for older adults: A literature based framework (MOLD-US),” *International Journal of Medical Informatics* (114), pp. 66-75 (doi: 10.1016/j.ijmedinf.2018.03.012).

Wyatt, T. H., Bayless, A. K., Krauskopf, P., and Gaylord, N. 2021. “Using mHealth Applications to Promote Self-Managed Health Behaviors Among Teens,” *Journal of Pediatric Nursing* (59), pp. 164-172 (doi: 10.1016/j.pedn.2021.04.025).

Xu, L., Sanders, L., Li, K., and Chow, J. C. L. 2021. “Chatbot for Health Care and Oncology Applications Using Artificial Intelligence and Machine Learning: Systematic Review,” *JMIR Cancer* (7:4), e27850 (doi: 10.2196/27850).

Y Zhang, C Liu, S. L., Y Xie, F Liu, X Li, and Z Zhou. 2019. *Factors influencing patients' intentions to use diabetes management apps based on an extended unified theory of acceptance and use of technology model …*

Yaqoob, I., Salah, K., Jayaraman, R., and Al-Hammadi, Y. 2022. “Blockchain for healthcare data management: opportunities, challenges, and future recommendations,” *Neural Computing and Applications* (34:14), pp. 11475-11490 (doi: 10.1007/s00521-020-05519-w).

Yuan, S., Ma, W., Kanthawala, S., and Peng, W. 2015. “Keep Using My Health Apps: Discover Users' Perception of Health and Fitness Apps with the UTAUT2 Model,” *Telemedicine journal and e-health : the official journal of the American Telemedicine Association* (21:9), pp. 735-741 (doi: 10.1089/tmj.2014.0148).

Zelmer, J., van Hoof, K., Notarianni, M., van Mierlo, T., Schellenberg, M., and Tannenbaum, C. 2018. “An Assessment Framework for e-Mental Health Apps in Canada: Results of a Modified Delphi Process,” *JMIR mHealth and uHealth* (6:7), e10016 (doi: 10.2196/10016).

Appendix

Interview Questionnaire

Frage auf Englisch	Frage auf Deutsch	Source/Model
UTAUT 2 Modell Fragen:		
How do you think using this smart city application could improve your physical activity and health?	Was glauben Sie, wie die Nutzung dieser Smart-City-Application Ihre körperliche Aktivität und Gesundheit verbessern könnte?	UTAUT 2 (Performance Expectancy)
How do you think the application can encourage you to be more physically active?	Wie kann die Application Ihrer Meinung nach zu mehr körperlicher Aktivität anregen?	UTAUT 2 (Performance Expectancy)
Can you imagine how easy or difficult it might be to use this smart city application to increase your physical activity? Please share what you know or suspect about the application.	Können Sie sich vorstellen, wie einfach oder schwierig es sein könnte, diese Smart-City-Application zu nutzen, um Ihre körperliche Aktivität zu steigern? Bitte teilen Sie mit, was Sie über die Application wissen oder vermuten.	UTAUT 2 (Effort Expectancy)
How much enjoyment and pleasure do you anticipate from using this smart city application to promote physical activity?	Wie viel Spaß und Freude versprechen Sie sich von der Nutzung dieser Smart-City-Application zur Förderung der körperlichen Aktivität?	UTAUT 2 (Hedonic Motivation)
Do you frequently include technical tools (such as applications) into your regular routine?	Nutzen Sie in Ihrem täglichen Leben häufig Technologien oder Applications? Welche Technologien oder Applications verwenden Sie normalerweise?	UTAUT 2 (Habit)
Do you think you will use a physical activity application regularly? If yes, why, and if no, why not?	Glauben Sie, dass Sie eine Application für körperliche Aktivität regelmäßig nutzen werden? Wenn ja, warum, und wenn nein, warum nicht?	UTAUT 2 (Habit)
How often do you think you will use this smart city application to get around? Please explain your answer.	Wie oft werden Sie diese Smart-City-Anwendung nutzen, um sich zu bewegen? Bitte erläutern Sie Ihre Antwort.	UTAUT 2 (Behavioral Intention)
What aspects do you think will influence your choice to use the health application?	Welche Aspekte oder Anreize würden Sie dazu ermutigen, die Application zur Förderung körperlicher Aktivität häufiger zu verwenden?	UTAUT 2 (Behavioral Intention)

How frequently do you anticipate utilizing the application to engage in physical exercise on a weekly basis?	Was denken Sie, wie oft werden Sie die Application in der Woche verwenden?	UTAUT 2 (Actual Use)
What situations or settings do you think you will use the application in the most frequently?	In welchen Situationen oder Kontexten werden Sie die Application Ihrer Meinung nach am häufigsten verwenden?	UTAUT 2 (Actual Use)
Health Belief Modell Fragen:		
How often and for how long per week do you currently participate in sporting activities or engage in physical activity? Please estimate the average number of minutes per week you spend on such activities.	Wie oft und wie lange pro Woche treiben Sie derzeit Sport oder üben körperliche Aktivitäten aus? Bitte schätzen Sie die durchschnittliche Anzahl der Minuten pro Woche, die Sie mit solchen Aktivitäten verbringen.	Health Belief Modell
How do you view your susceptibility to illnesses like physical inactivity or other conditions?	Wie schätzen Sie Ihr Risiko für Krankheiten wie körperliche Inaktivität oder andere Beschwerden ein?	Health Belief Modell
What degree do you consider the health dangers of inactivity?	Inwieweit halten Sie die gesundheitlichen Risiken von körperlicher Inaktivität für ernst?	Health Belief Modell
What benefits do you expect from using a smart city application to promote physical activity and improve health, and to what extent?	Welche Vorteile versprechen Sie sich von der Nutzung einer Smart-City-Application zur Förderung der körperlichen Aktivität und zur Verbesserung der Gesundheit, und in welchem Umfang?	Health Belief Modell
Have you ever used a similar application to improve your health? If so, what difficulties or barriers do you see in using such an application? This could include things like installing the application, setting up user accounts, or other related processes.	Haben Sie jemals eine ähnliche Application verwendet, um Ihre Gesundheit zu verbessern? Wenn ja, welche Schwierigkeiten oder Hindernisse sehen Sie bei der Nutzung einer solchen Application? Dazu könnten Dinge wie die Installation der Application, die Einrichtung von Benutzerkonten oder andere damit verbundene Prozesse gehören.	Health Belief Modell
Can you describe how confident you are in using the Smart City application regularly and successfully to improve your physical fitness and health?	Können Sie beschreiben, wie zuversichtlich Sie sind, die Smart-City-Application regelmäßig und erfolgreich zu nutzen, um Ihre körperliche Fitness und Gesundheit zu verbessern?	Health Belief Modell

Demografische Fragen: Bei keiner Angabe N/A		
What is your gender?	Welchem Geschlecht identifizieren Sie sich?	Demographics
How old are you?	Wie alt sind Sie?	Demographics
What is your highest educational attainment?	Was ist Ihr höchster Bildungsabschluss?	Demographics
Are you married, single, divorced, widowed, or in a partnership?	Sind Sie verheiratet, ledig, geschieden, verwitwet oder in einer Partnerschaft?	Demographics
What is your current occupation or profession?	In welcher beruflichen Tätigkeit sind Sie derzeit hauptsächlich tätig?	Demographics
In which type of area do you currently live?	In welchem Gebiet leben Sie derzeit? (Stadt, Vorort, ländliche Gegend reicht auch als Antwort)	Demographics

Interview Questionnaire 2

Frage auf Englisch	Frage auf Deutsch	Source/Model
How would you rate your experience with the application?	Wie würden Sie Ihre Erfahrungen mit der Application bewerten?	Actual User Experience
Did you appreciate certain features of the application that you particularly liked or disliked?	Haben Sie bestimmte Funktionen der Application besonders geschätzt, die Ihnen gefallen oder nicht gefallen haben?	Performance Expectancy (PE)
Has the application helped you improve your fitness and health?	Hat die Application Ihnen geholfen, Ihre Fitness und Gesundheit zu verbessern?	Behavioral Intention (BI)
Were there any problems or obstacles you encountered while using the application?	Sind Sie bei der Nutzung der Application auf Probleme oder Hindernisse gestoßen?	Effort Expectancy (EE)
In which situations or contexts have you actually used the application?	In welchen Situationen oder Kontexten haben Sie die Application tatsächlich verwendet?	Actual Use (AU)
How many Challenge-points did you accumulate in the application for physical activity?	Wie viele Challenge-Punkte haben Sie in der Application für körperliche Aktivität gesammelt?	Actual Use (AU)
How often did you use the application during this test phase?	Wie oft haben Sie die Application während dieser Testphase genutzt?	Actual Use (AU)

Did you maintain your intention to use the application for physical activities during the test phase?	Haben Sie Ihre Absicht, die Application für körperliche Aktivitäten zu nutzen, während der Testphase beibehalten?	Behavioral Intention (BI)
What motivated you during the test phase to continue using the physical activity application?	Was hat Sie während der Testphase motiviert, die Application für körperliche Aktivität weiter zu nutzen?	Hedonic Motivation
During the test phase, the application has become an integral part of their daily routine?	Während der Testphase ist die Anwendung zu einem festen Bestandteil ihrer täglichen Routine geworden?	Habit
Have you experienced support from friends and family in using the physical activity application during this trial period?	Haben Sie während der Testphase Unterstützung von Freunden und Familie bei der Nutzung der Application für körperliche Aktivität erfahren?	Social Influence (SI)
Have you noticed improvements in your overall health and physical activity when using the application?	Haben Sie bei der Nutzung der Application Verbesserungen in Bezug auf Ihre allgemeine Gesundheit und körperliche Aktivität festgestellt?	Health Belief Model (HBM)
Were there any problems or obstacles during the test phase that prevented you from using the application during physical activities?	Gab es während der Testphase Probleme oder Hindernisse, die Sie daran gehindert haben, die Application bei körperlichen Aktivitäten zu nutzen?	Effort Expectancy (EE)
Have you recommended the application to your friends or family, and if so, what was their reaction or experience?	Haben Sie oder würden Sie die Application Ihren Freunden oder Ihrer Familie empfohlen, und wenn ja, wie haben sie reagiert oder welche Erfahrungen haben sie gemacht?	Social Influence (SI)
Were there any unexpected advantages or disadvantages in using the application during the test phase?	Gab es während der Testphase unerwartete Vor- oder Nachteile bei der Nutzung der Application?	Health Belief Model (HBM)

Do you have any additional feedback or comments about your experience with the application during the testing phase?	Haben Sie zusätzliches Feedback oder Kommentare zu Ihren Erfahrungen mit der Application während der Testphase?	Individual Factors

Transcripts Interview 1


P1_Interview1.txt


P1011_Interview1_Teil1.txt


P12_Interview1.txt


P11_Interview1_Teil3.txt


P11_Interview1_Teil2.txt


P10_Interview1_Teil2.txt


P9_Interview1.txt


P8_Interview1.txt


P7_Interview1.txt


P6_Interview1.txt


P5_Interview1.txt


P4_Interview1.txt


P3_Interview1.txt


P2_Interview1.txt

Transcripts Interview 2


P1011_Interview2.txt


P89_Interview2.txt


P7_Interview2.txt


P6_Interview2.txt


P5_Interview2.txt


P4_Interview2.txt


P3_Interview2.txt


P1_Interview2.txt