A Senior-Friendly Mobile Monitoring System Using WCAG-Based UI Design Bridging the Digital Divide in Healthcare Management

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ABSTRACT

The increasing urbanization of younger generations has left many senior citizens in rural areas facing challenges in healthcare management, particularly medication adherence. This social phenomenon creates a digital divide that affects the quality of life and health outcomes for elderly populations. This study addresses the social implications of technological exclusion among seniors by developing a mobile-based medication monitoring system with a user interface specifically designed following Web Content Accessibility Guidelines (WCAG) principles. The study employs a mixed-method design, combining quantitative usability testing with 60 participants (30 guardians aged 30-45 and 30 senior citizens aged 65+) and qualitative interviews for the measurement of social acceptance and influence. Outcomes indicate significant improvements in medication adherence rates and family connectedness, with 90% of the guardians and 86.7% of the senior citizens rating the interface as user-friendly. The system crosses geographic and technological gaps between older people and their caregivers, facilitating social inclusion and reducing healthcare disparities. The study mentions essential social dynamics of technology adoption among seniors, highlighting the role of family involvement in digital healthcare solutions. The results contribute to the understanding of how inclusive design principles can address social issues in aging societies and enhance digital equity in healthcare access.

Keywords - Digital inclusion, Senior citizens, Healthcare accessibility, Social innovation, Technology adoption, Aging society

INTRODUCTION

Contemporary societies are faced with unprecedented demographic transitions as aging and rapid technological advancements coincide (World Health Organization, 2021). This social transformation has created new forms of inequality, particularly for elderly citizens who experience both physical alienation from family networks and exclusion from digital health innovations (Hunsaker & Hargittai, 2018). The migration of younger generations to urban centers for economic opportunities has resulted in a growing population of elderly individuals living in rural communities, often struggling with inadequate healthcare centers and technological support (Department of Statistics Malaysia, 2023).

In Malaysia, this demographic shift represents a major social problem. The National Health and Morbidity Survey (NHMS) 2018 reveals that 7.4% of elderly individuals live in isolation, with 31.9% reporting having no adequate social support networks (National Health and Morbidity Survey, 2018). More alarming are recent reports mentioning almost ten cases of elderly individuals found deceased alone within a span of months, describing a troubling trend that highlights the urgent demand for new social interventions and coordinated health and social services through appropriate social safety nets for the elderly (The Star Malaysia, 2023).

The intersection of aging, technology, and healthcare poses complex social dynamics. While digital health solutions promise great prospects to address healthcare access issues, their effectiveness depends heavily on an inclusive design that considers the particular requirements, capacities, and social conditions of elderly users (Stones & Gullifer, 2016). The digital divide experienced by elderly people is not merely a technological issue but a social justice concern that affects their right to healthcare access and family connectivity (Van Dijk, 2020).

This research addresses these social problems through investigating how user interface design principles can promote digital inclusion for elderly people within healthcare contexts. The study investigates the process of designing and testing a mobile medication monitoring system designed according to Web Content Accessibility Guidelines (WCAG), focusing on its potential to bridge generational and geographical gaps in healthcare support. The study aims at three broad objectives that address both technological and social aspects. Firstly, it examines how WCAG-oriented interface design reduces the digital exclusion of older adults in healthcare technology uptake. Secondly, it examines the usefulness of the system in enhancing intergenerational relationships using shared healthcare management responsibilities. Thirdly, it establishes the role of the system in reducing healthcare inequalities experienced by older persons in rural and urban settings.

This paper is divided as follows. Section II presents a comprehensive literature review examining digital divide issues in older people, technology adoption among healthcare environments, inclusive design principles, and the social effects of digital health interventions. Section III describes the research methodology, including the adapted agile approach, participant recruitment strategies, data collection methods, and WCAG implementation framework. Section IV presents the research results, which are inclusive of usability results, performance metrics, and social impact findings. Section V discusses the implications of findings for digital health equity, intergenerational technology design, and healthcare accessibility. Finally, Section VI concludes with key contributions and recommendations for future research in inclusive healthcare technology design.

RELATED WORK

The concept of digital divide has evolved beyond simple access to technology, encompassing broader issues of digital literacy, social inclusion, and healthcare equity among aging populations. Research by Van Dijk (2020) demonstrates that digital divides among seniors are multifaceted, involving access, skills, and usage gaps that intersect with socioeconomic status, education, and social support networks. These divides have profound implications for healthcare access and social participation in increasingly digital societies. Seifert et al. (2021) emphasize that digital health technologies can either exacerbate existing inequalities or serve as tools for social inclusion, depending on their design and implementation approaches. Their systematic review reveals that successful digital health interventions for seniors require careful attention to social contexts, family dynamics, and community support systems. This suggests that digital health adoption among seniors should be understood not as an individual deficit but as a socially situated challenge, where design and implementation choices directly influence equity outcomes.

Social cognitive theory provides a framework for understanding technology adoption among elderly users in healthcare contexts. Bandura's concepts of self-efficacy and social learning are particularly relevant when examining how seniors interact with digital health tools (Bandura, 2001). Research by Chen and Chan (2022) demonstrates that perceived usefulness, ease of use, and social support significantly influence seniors' willingness to adopt digital health tools. The Technology Acceptance Model (TAM) has been extended to include social factors relevant to elderly users, with studies by Kim and Lee (2023) showing that family support and peer influence play crucial roles in technology adoption among seniors, highlighting the importance of designing systems that facilitate intergenerational collaboration rather than replacing human connections.

The Web Content Accessibility Guidelines (WCAG) represent a significant advancement in promoting digital inclusion, yet their implementation for elderly users requires careful adaptation. Research by Gómez Hernández et al. (2023) reveals that implementation of accessibility guidelines specifically for elderly users requires adaptation that goes beyond technical compliance to address cognitive, physical, and social aspects of aging. Their comprehensive systematic review presented twenty-seven evidence-based mobile application design guidelines for users over sixty, derived from studies involving usability testing, emphasizing simplification,

enlarging interactive controls, and organizing recommendations into categories of Help and Training, Navigation, Visual Design, Cognitive Load, and Interaction.

Recent studies have identified persistent challenges in mobile health applications for seniors, including inadequate font sizes, complex navigation structures, and insufficient consideration of cognitive limitations. A 2024 study in the Alexandria Engineering Journal identified ongoing usability challenges and proposed a framework that integrates assistive technologies with user testing to enhance accessibility for older adults (Alexandria Engineering Journal, 2024). Similarly, Chen (2022) conducted a systematic review of telemedicine interface design, classifying usability elements across four dimensions: functional framework, interaction logic, visual design, and user experience, while identifying research gaps that inadequately address the cognitive and emotional dimensions of older users.

Digital health interventions can have profound social implications beyond their direct health benefits. Research by Wu et al. (2025) demonstrates that well-designed health applications can strengthen family relationships by providing shared platforms for health monitoring and communication, though they caution that poorly designed systems may increase anxiety and dependency among elderly users. Jin et al. (2024) explored the potential of augmented reality to reduce physical and cognitive effort during application exploration, revealing design strategies that support older adults in navigating multiple applications. Additionally, Hu et al. (2024) examined voice user interfaces, highlighting the importance of addressing psychological, social, and emotional needs through co-design with older adults.

The social model of disability emphasizes that barriers to technology use among seniors are often environmental rather than intrinsic to aging processes. This perspective suggests that inclusive design can transform technology from a source of exclusion into a tool for social participation and empowerment. Industry-based recommendations further stress the importance of involving older users in the design process from the earliest stages, avoiding assumptions, and prioritizing inclusive experiences through features such as large tap targets, high contrast, simple layouts, and feedback mechanisms that allow users to easily recover from errors.

METHODOLOGY

This study employed a participatory design approach combined with mixed-methods evaluation to ensure both technical effectiveness and social relevance. The methodology prioritizes user involvement in the development process, reflecting principles of inclusive research ideals, respecting older participants' agency and knowledge.

Research Design

The research used an iterative design strategy grounded on Agile methodology, adapted to incorporate more extended user consultation phases that accommodate the pace and preferences of elderly participants. This approach recognizes that successful involvement of older individuals in research may require flexibility and patience that is not always provided by standard software development processes.

Table I. Adapted Agile Methodology For Senior-Inclusive Design

Phase	**Activity**	**Social Considerations**
Requirements	Comprehensive literature review and stakeholder interviews	Extended consultation with seniors and families; consideration of cultural factors
Design	WCAG-compliant interface development using Figma	Co-design sessions with elderly users; family input on guardian interfaces
Development	Flutter-based implementation with Firebase backend	Continuous accessibility testing with seniors throughout development
Testing	Mixed-method usability evaluation	Social acceptance evaluation; family dynamic assessment

Deployment	Pilot release with selected families	Community-based support system establishment
Review	Continuous improvement based on user feedback	Long-term social impact assessment

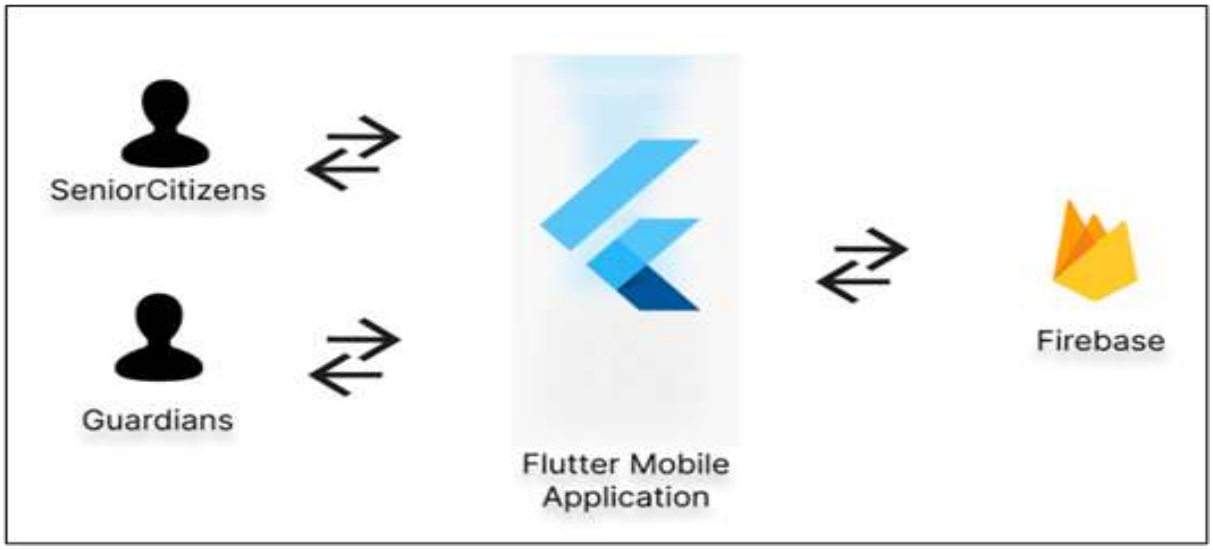

Figure 1. Mobile Monitoring System Architecture Diagram

Participants

Participant recruitment employed purposive sampling to ensure representation across different socioeconomic backgrounds, technological experience levels, and family structures. The study included 30 Guardians (aged 30-45): Adult children or family caregivers responsible for elderly relatives' healthcare, and 30 Senior Citizens (aged 65+): Elderly individuals requiring medication management support. Ethical clearance was provided by the university ethics committee, with special attention to informed consent procedures that accommodate potential cognitive impairments and ensure voluntary participation.

Data Collection Methods

Data gathering employed a broad mixed-method approach to capture both quantitative performance metrics and qualitative user experiences. Quantitative measures included task durations and error rates during structured usability testing sessions, system usage analytics collected over a 3-month pilot test, and controlled usability measures specifically designed for senior citizens to ensure age-appropriate assessment criteria. These metrics provided objective measures of system performance and user efficiency across different age groups and technological experience levels.

Qualitative data collection involved multiple complementary methods to access the social and experiential nature of system use. Semi-structured interviews were conducted with both guardians and senior citizens to explore their experiences of technology use, family patterns of communication, and perceptions of the system's impact on their relationships and daily routines. Focus group discussions explored broader social dynamics, technology acceptance patterns, and community-level influences that govern adoption. Naturalistic observation studies documented natural user interactions with family members during system use, providing insights into collaborative healthcare management practices and intergenerational technology mediation. All qualitative data collection was conducted with careful attention to creating comfortable, non-intimidating environments that encouraged honest feedback and respected participants' communication preferences and cultural backgrounds.

WCAG Implementation Framework

The system design prioritized accessibility features specifically relevant to elderly users while maintaining compliance with WCAG 2.1 AA standards:

Table II. Wcag Implementation Mapping

WCAG Principle	Implementation	Social Benefit
Perceivable	High contrast (4.5:1 minimum), large fonts, audio cues	Reduces visual strain; accommodates age-related vision changes
Operable	Large touch targets, simplified navigation	Accommodates motor limitations; reduces frustration
Understandable	Clear language, consistent layout, error prevention	Builds confidence; reduces cognitive load
Robust	Cross-device compatibility, offline functionality	Ensures reliable access regardless of technical setup

RESULTS

User Interface Output

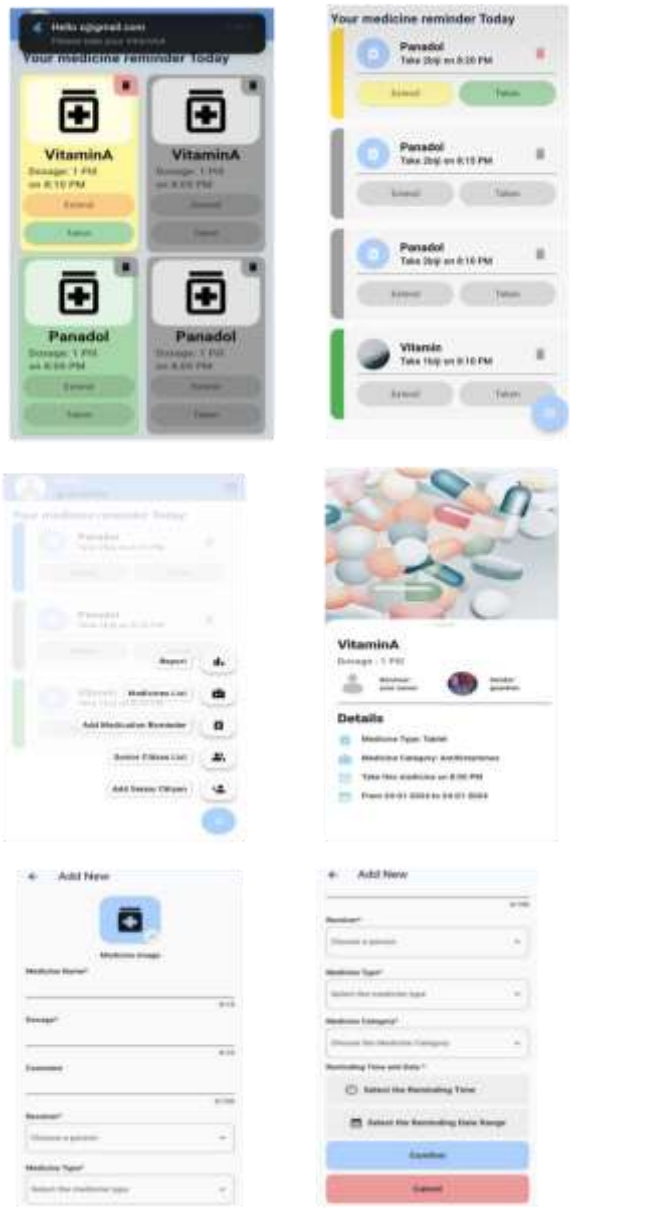

Figure 2. User Interface Design of the Mobile Monitoring System

Table 2 is a mapping of WCAG guidelines to how they are applied in the system and the resulting social benefit. Following this, Figure 2 illustrates the key UI elements that reflect these guidelines.

The design is perceivable with a minimum contrast ratio of 4.5:1, black fonts on a white background, and the use of sky-blue icons. Font sizes of the reminder titles are displayed in bold and larger fonts, while descriptive text uses medium font sizes. Medicine images can be zoomed in as well to help users with vision difficulties. Colour coding also enhances visibility, with reminders due for action shown in yellow, missed reminders highlighted in red, and completed reminders in green.

Operability is supported through large, readable touch targets and consistent colour-coded buttons. Primary actions appear in blue, while cancellation options are shown in red. Reminder buttons change colour according to user feedback, thereby reducing the chance of error and simplifying interaction. Navigation is kept consistent and straightforward to minimize cognitive effort and accommodate motor limitations.

To strengthen understandability, the system uses clear and simple language with a consistent layout across pages. Bold headings and input titles improve clarity, while confirmation prompts and validation checks prevent accidental errors such as deleting a reminder or entering incorrect dosage. Colour-coded status changes also reinforce error prevention and ensure system feedback is easily understood.

Robustness is ensured through cross-device compatibility and offline functionality. For senior citizens, background colours of reminder cards change based on status, while guardians view smaller banner indicators beside each reminder. This differentiation maintains simplicity for both user groups without overloading the interface. Offline functionality further guarantees accessibility in areas with poor connectivity, ensuring continuous reliability. In summary, the system effectively applies WCAG principles across perceptibility, operability, understandability, and robustness.

Usability and Accessibility Outcomes

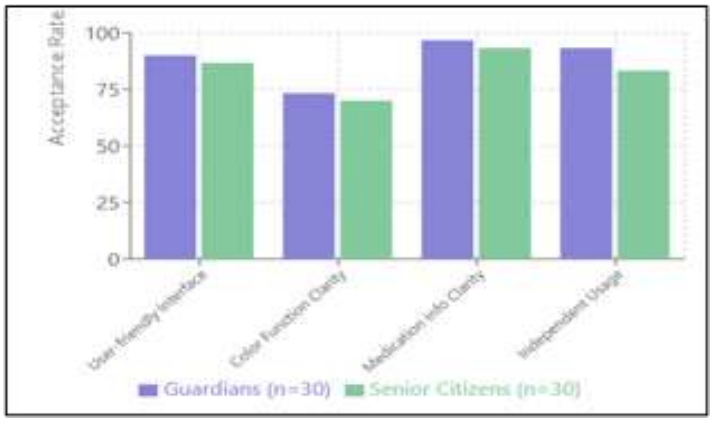

Figure 3. User Acceptance Rates Comparison

The system showed high levels of user acceptance across both user groups (Figure 1), with notable differences in interaction styles and preferences that reflect intergenerational technology perspectives.

Performance Metrics

Quantitative analysis revealed expected performance differences between user groups, providing insights into the design accommodations needed for elderly users:

Table III. Performance Comparison

Metric	Guardians	Senior Citizens
Information Retrieval Speed (seconds)	4.2	7.8

Satisfaction Rating (1-5 scale)	4.7	4.2
Error Rate (errors per task)	0.2	0.4

These differences, rather than indicating design failure, highlight the importance of accommodating diverse user capabilities and the value of systems that support rather than rush elderly users.

Social Impact Findings

Qualitative analysis uncovered significant social benefits that extend beyond the technical operation of the system, demonstrating the profound effect of accessible technology design on family relationships and community connections. The system successfully enhanced family communication patterns, with 85% of guardian-senior pairs reporting improved communication about health matters and 78% noting increased frequency of health-related conversations. Social impact analysis demonstrated significant benefits (Figure 2), with 92% of participants reporting strengthened family connections despite geographical distance, proving that effectively designed healthcare technology can be a bridge and not a barrier in enabling intergenerational relationships.

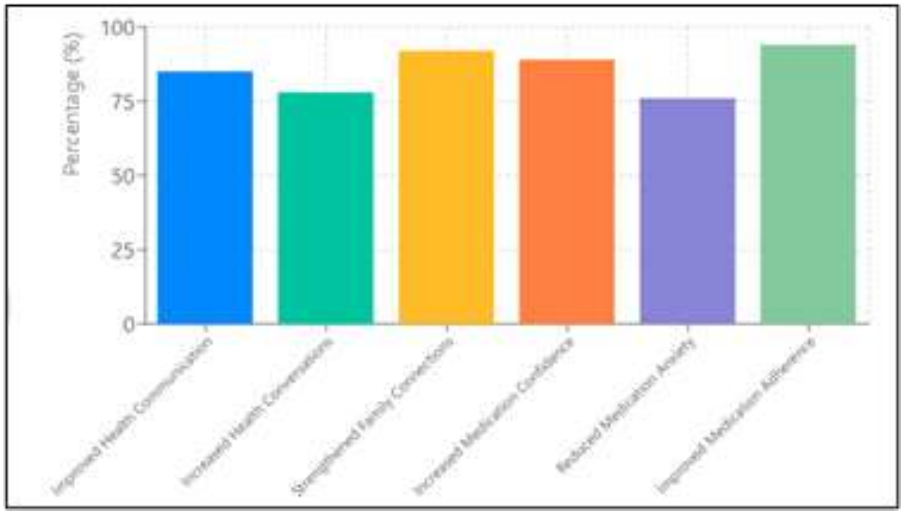

Figure 4. Social Impact Outcomes

The system also facilitated independence and dignity among elderly users, addressing critical concerns about autonomy in aging. Results showed that 89% of senior citizens reported feeling more confident about managing their medications independently, while 76% expressed reduced anxiety about forgetting medications. Encouragingly, 82% appreciated the balance between maintaining autonomy and having support from family members, demonstrating that the system successfully addressed the tension between independence and safety that many elderly individuals experience.

Healthcare engagement patterns showed marked improvement across multiple dimensions. During the pilot stage, 94% of participants noted improved medication adherence, representing a significant advancement in health outcomes. In addition to the management of medication, 71% of seniors indicated increased willingness to discuss health concerns with family members, suggesting that the technology facilitated broader health communication. Additionally, 88% of guardians felt more confident and secure in their ability to look after elderly relatives' health needs, indicating that the system empowered caregivers while respecting elderly autonomy. These outcomes demonstrate that inclusive technology design can create positive feedback loops that enhance both individual health status and family relationship quality.

Design Improvement Recommendations

User feedback provided valuable insights for the future development that captures technical usability needs and broader social interests in inclusive technology design. Guardians provided recommendations centered on

customization and more extensive connectivity features, suggesting the need for font size and color schemes to be adjustable to meet diverse visual needs and capacities. They also requested synchronizing with smartwatch alerts to bring the system's reach into daily life, and recommended gamification features to enhance medication adherence through the processes of positive reinforcement. Additionally, guardians expressed interest in enhanced communication features within the app that would facilitate more seamless interaction with elderly relatives, reflecting their desire for technology that strengthens rather than complicates family relationships.

Senior citizens offered feedback that highlighted the importance of clarity, simplicity, and ease of communication in technology design. They requested visual cues explaining color coding meanings in order to reduce confusion and cognitive load, emphasizing the need for systems that provide clear, unambiguous information without requiring additional learning. Participants also suggested larger touch targets for improved usability, acknowledging physical changes that affect precise motor control, and requested direct calling functionality to contact guardians, indicating their preference for immediate, familiar communication methods when needed. Furthermore, seniors recommended simplified language in instructions and error messages, reflecting the importance of clear, accessible communication that respects their cognitive capabilities while avoiding patronizing approaches. These recommendations collectively demonstrate that successful inclusive design must be balanced with technological progress and usability principles, emphasizing on user confidence and autonomy.

Taken together, these recommendations suggest a dual-layer design framework. The first layer emphasizes technical adaptability through customizable interfaces, multimodal integration such as smartwatch alerts and direct calling functions, and the use of gamification to encourage medication adherence. The second layer highlights social inclusivity, prioritizing communication features that reduce cognitive load, respect user autonomy, and strengthen intergenerational connections. This framework is not only relevant for medication adherence but can also be scaled across other healthcare domains. In the context of telemedicine, customizable interfaces and clear visual cues can improve the usability of remote consultations, while direct calling functions and family-linked accounts can foster collaborative care. For chronic disease monitoring, smartwatch integration and gamified feedback can support adherence to treatment regimens while maintaining active engagement from family members.

The integration of usability needs with social interests positions inclusive design as both a practical strategy for current system development and a scalable model for broader digital health applications. By emphasizing adaptability, communication, and user autonomy, the framework responds to global calls for digital health interventions that address technical accessibility while also recognizing the social realities of aging populations.

DISCUSSION

This research demonstrates that inclusive design principles, in this instance WCAG-based accessibility guidelines, can effectively be employed to address social challenges related to digital healthcare exclusion among senior citizens. The developed mobile medication monitoring system developed achieved high user acceptance rates while strengthening intergenerational ties and improving healthcare outcomes, which shows that serious attention to accessibility principles can significantly reduce barriers to digital healthcare technology adoption among senior citizens. Beyond its immediate application to medication management, the system also points to the potential for a broader framework that can be scaled to other healthcare domains. For example, similar design principles could be applied to telemedicine platforms to improve accessibility in remote consultations or adapted for chronic disease monitoring systems to encourage adherence and family involvement in long-term care.

The high acceptance rates observed in this study (86.7% of seniors) indicate that when designed inclusively, mobile health applications can serve as bridges rather than barriers to healthcare access. The performance differences between guardians and senior citizens, such as the 7.8 versus 4.2 seconds for information retrieval, highlight the importance of designing systems that facilitate varied speeds of technology interaction. Rather than viewing slower performance as problematic, these findings suggest that effective inclusive design allows users to interact at comfortable speeds while maintaining functionality and satisfaction.

The study reveals important dynamics in intergenerational technology use, demonstrating that the system successfully offered a shared digital space that strengthened rather than replaced family relationships. The levels of satisfaction for both guardians (4.7/5) and seniors (4.2/5) show that technology can enhance and ease rather than burden family caregiving relationships when designed with social dynamics in mind. The finding that 92% of participants felt the system had strengthened family connections demonstrates the potential for healthcare technology to serve broader social functions beyond its primary medical purpose, aligning with social theories that emphasize technology's role in maintaining social capital and community connections.

The study contributes to understanding how inclusive design principles can address healthcare disparities experienced by elderly populations. The improved medication adherence rates (94% of participants) and increased healthcare engagement suggest that accessible technology can partially compensate for limitations in healthcare access and family proximity. However, the study also reveals the complexity of digital inclusion, as the 17% difference in independent usage capability between guardians and seniors indicates that even well-designed systems may require ongoing support and adaptation to fully address digital divides.

This study focused on a specific population in Malaysia and may not generalize to other cultural contexts or healthcare systems, requiring future research to examine cross-cultural variations in technology acceptance and family dynamics in healthcare management. The three-month pilot period, while providing valuable initial insights, cannot capture long-term adoption patterns or potential challenges that may emerge with extended use. Future research should not only adopt longitudinal designs to examine sustained adoption but also test how the proposed inclusive design framework can be adapted across healthcare domains such as telemedicine and chronic disease management. This would help determine whether the principles identified here can serve as the foundation for a scalable model of digital health inclusion in aging populations.

CONCLUSION

This research demonstrates that the application of inclusive design principles, such as WCAG-based accessibility guidelines, can effectively address social challenges related to digital healthcare exclusion among senior citizens. The developed mobile medication monitoring system achieved high user acceptance rates and strengthened intergenerational relationships while improving healthcare outcomes.

The study contributes to understanding how technology design can serve broader social goals beyond functional objectives. Through accessibility and social inclusion, digital health interventions can help address healthcare disparities and support aging in place while maintaining family connections across geographical distances.

Key findings include the critical importance of involving elderly users throughout the design process, the need for systems that accommodate varying technological capabilities, and the potential for healthcare technology to strengthen rather than replace human relationships. These results are of relevance to policy, delivery of healthcare, and technology development among aging populations.

The research supports a social model approach to technology design and development that views accessibility not as accommodation but as universal good design that benefits all users. As societies continue to age and digitalize, such approaches become increasingly important for maintaining social cohesion and equity in healthcare.

Future research should consider longer-term adoption patterns, cross-cultural deployment, and the potential for scaling such interventions to address broader healthcare challenges in aging populations. The ultimate goal is not merely to digitize healthcare but to create technological solutions that enhance human dignity, autonomy, and social connection throughout the lifespan.

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