RESEARCH-ARTICLE

Toward a Multi-layer Framework to Assess the Quality of Life Impact of Smartphones as Assistive Technology for People with Sensory Disabilities in Kenya

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Abstract

Recent advances in smartphone technology have elevated their potential as digital assistive technologies (AT) for blind or partially sighted (BPS) and deaf or hard of hearing (DHH) individuals. However, there is a gap in fully understanding the use of smartphones as AT and their impact on the quality of life (QoL) of BPS and DHH individuals. To address this gap, we conducted a mixed-methods longitudinal study over six months with 193 participants in Kenya. The study involved a baseline survey, smartphone digital skills training, and a follow-up survey and interviews to examine the impact of smartphones as AT. The findings emphasise the significant impact of smartphones on their quality of life, including impact on their identity and well-being, social inclusion and leisure, access to information and education, and material well-being. Building on the findings, we contribute an AT Impact Framework, which highlights the behaviours enabled by smartphones and their impact on the individual and their wider ecosystem. We discuss the applications of the AT Impact Framework to assess the impact on QoL outcomes of AT interventions and offer recommendations for policymakers, researchers, and designers.

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CCS Concepts

• **Human-centered computing → Empirical studies in accessibility**; **Accessibility design and evaluation methods**.

Keywords

Accessibility; People with Disabilities & Assistive Technologies; Blind and Partially Sighted, Deaf and Hard of Hearing; Mobile Devices: Phones/Tablets; Field Study; Interview; Qualitative Methods; Quantitative Methods; Survey

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1 Introduction

Over the past two decades, smartphones have evolved from simple communication devices to powerful, multifunctional tools that can significantly enhance the lives of disabled individuals. As assistive technology (AT), smartphones offer a wide range of functionalities, including accessibility features, applications, and Internet connectivity, that allow disabled individuals to overcome various accessibility barriers. Unlike traditional physical assistive devices, such as braille readers and hearing aids, which are often expensive and difficult to obtain in low-resource settings, affordable smartphones are widely available in lower and middle income countries (LMICs), such as Transsion, Xiaomi, Oppo, and Realme [51, 65], which run on Google's Android operating system, allowing a certain level of consistency across different smartphone manufacturers and models.

The Global Systems for Mobile Technology Association (GSMA) estimates that approximately 85% of the African population owns a mobile phone. Although the ownership of feature phones (button phones without Internet-enabled applications) continues to increase rapidly, there is also a more modest but steady uptake in smartphone ownership. A recent GSMA report estimates smartphone ownership between 42% and 56% of adults across various Sub-Saharan African regions, with rates expected to reach 80% to 92% by 2030 [23]. However, this number is significantly reduced for disabled individuals; in Kenya, smartphone ownership by disabled individuals is only 12% compared to 41% non-disabled population (a 72% gap in smartphone ownership)[22]. The gap, termed the 'digital divide' is largely due to persistent challenges, including awareness, affordability, accessibility, and digital literacy [18, 39, 47, 64].

Smartphones offer several key benefits for disabled individuals. For blind and partially sighted (BPS) individuals, smartphones offer screen readers and voice command features, allowing users to navigate applications (apps), access information, and communicate without visually interacting with the device. For deaf and hard-of-hearing (DHH) individuals, smartphones support video calls to allow communication in sign language, live transcription, and text-based communication, improving social interaction and independence. In addition, smartphone apps, including instant messaging, social networks, navigation, and learning, offer a wide variety of options and services for people with diverse needs. This combination supports and improves connectivity and inclusion [39, 47] and overcomes traditional accessibility issues [10].

As smartphones become more ubiquitous in daily life, understanding their impact on different populations, particularly the impact of smartphone accessibility features, becomes essential. To this end, we propose the following research question:

RQ1: How does access to smartphones impact the quality of life (QoL) of BPS and DHH individuals in Kenya?

RQ2: How do smartphones enable positive QoL outcomes that propagate their broader communities?

To address these research questions, we conducted a mixed-methods longitudinal study with 193 BPS and DHH participants based in Kenya, leading to important insights into the lived experiences of the participants as they integrated smartphones into their lives. Although we appreciate that smartphones can be beneficial to many sub-sections of the disability community, we chose to focus on the BPS and DHH communities for this research due to the increasing number of accessibility features such as TalkBack, Google Assistant, and Lookout that were designed for BPS individuals and Live Transcribe, Live Captions, and Sound Amplifications designed to address the needs of DHH individuals. In this paper, we contribute:

- Empirical findings from a mixed-methods study evaluating the impact of smartphones as AT for BPS and DHH individuals in Kenya.
- An AT Impact Framework derived from the findings, which builds on existing QoL and behaviour frameworks to unpack how access to smartphones can have a positive impact at individual, community, and societal levels.
- Recommendations for designing policies to maximise the impact of digital assistive technologies and support the design of emerging mobile technologies that meet the needs of BPS and DHH users.

2 Related work

This research builds on existing research on access and adoption of assistive technologies in LMICs, smartphones as assistive technologies in LMIC, and the impact of AT on quality of life.

2.1 Smartphone Adoption in LMICs

Smartphone adoption has grown steadily in LMICs in the last few years. Initially, adoption was predominantly by males with relatively high levels of education and income living in urban settings [55]. However, now there is an increase in smartphone ownership and Internet connectivity among a diverse population and a subsequent positive contribution towards economic outcomes, contributing to the economic growth of emerging economies [4, 16, 17, 54]. Recent research on the use of smartphones among farmers in Kenya and Sub-Saharan Africa reveals increasing access to mobile services that provide agricultural and livestock information, facilitate product transactions and issue meteorological alerts, directly supporting their livelihoods and increasing the availability of produce in the region [38, 43]. The increased diversity of ownership is also reflected in the narrowing gender gap in smartphone use from 19% in 2022 to 15% in 2023, with an estimated 120 million women in LMICs adopting the mobile Internet in 2023 compared to 75 million men [24]. Furthermore, in 2023, Africa saw a higher adoption of smartphones amongst women than men in 2023 [21]. Although literacy, digital skills, and affordability remain prevalent challenges for women who own smartphones, these have a lower impact on the use of smartphones and the Internet compared to other types of technologies. For example, Garg et al. [19] found that nearly 85% of illiterate women used a smartphone without necessarily owning it, and smartphones are the main and often only source of communication and means of receiving information. However, the modalities by which women access smartphones and the purposes for which they access the Internet are still heavily influenced by gender dynamics, as shown in interviews conducted in West Bengal by Shaw, which show that the restrictions imposed by men in their lives often limited agency around when and how women could interact with smartphones and dictated priorities around mobile use to support children's education.

Similarly, access to smartphones for disabled individuals has also increased in LMICs. The 2020 GSMA Mobile Disability Gap [4] reported penetration rates of smartphones in eight countries in the Global South among disabled individuals from 41% in Bangladesh to 83% in Kenya. However, smartphone penetration rates were substantially lower, between 8% in Bangladesh and 39% in Mexico [4]. The report of the following year already showed marked increases in ownership rates, with India increasing from 57% to 61% for the overall ownership rate, and smartphone ownership in Nigeria jumped from 9% to 37% [22]. The accounts of 16 disabled individuals from Kenya and Bangladesh pointed out how smartphones could unlock access to benefits ranging from improved social connection, increased independence, and access to opportunities [34]. However, similar to what has been observed among other marginalised groups, access to smartphones and the agency around how to use them could be curtailed by power imbalances, systemic inequalities, lack of digital literacy, and limited support networks [32, 33, 36]. In contrast to other digitally marginalised groups, such as women or rural farmers, smartphones can play an even more fundamental role for disabled individuals, as they can offer substitute access to essential assistive technologies that are often unavailable in many areas of the Global South [9, 28, 30, 35, 52]. In the following section, we look at this aspect in more detail.

2.2 Smartphones as Assistive Technology

Smartphones are increasingly being considered a form of assistive technology, as accessible embedded features and downloadable applications assume roles that were once only possible in specific assistive products [9, 29]. For BPS and DHH individuals, smartphones support sensory substitution and enhancement. Embedded accessibility features of smartphones such as screen readers, speech-to-text, magnification and sound notifications have produced promising results to enable independence, access, and mobility for BPS and DHH individuals [1, 35, 59]. In addition, accessible and assistive smartphone applications such as Lookout, SeeingAI, BeMyEyes, Soundscape, and Aira use machine learning and artificial intelligence to further enhance the capability and usefulness of smartphones.

In the absence of universal access to assistive devices, such as braille readers, smart glasses, and hearing aids, smartphones have greater potential to serve as assistive technologies in low-resource settings. A recent study investigating the use of smartphones by wheelchair users in informal settings in Kenya found that wheelchair users used smartphones to connect with friends and family members when physical mobility was not possible and used mobile finance (such as M-Pesa) to manage their day-to-day expenses [10]. Similarly, a study of BPS in the same Kenyan setting highlighted the positive impact of smartphone use [8]. The study uncovered the ways in which BPS individuals use smartphones in close-knit communities and the role of friends and family members in supporting access to information and services. Both studies underscored the importance of accessible digital and physical infrastructures to fully empower BPS smartphone users to access services independently [8, 10].

Despite their potential, smartphone adoption as an AT faces significant challenges, particularly in LMICs. Barriers such as affordability, digital literacy, internet access, accessibility of the service infrastructure, and accessibility of mobile interfaces can limit their effectiveness [22, 23]. In particular, the high cost of modern smartphones and data plans restricts their affordability to people with disabilities in LMICs [4]. Therefore, many disabled individuals may not be able to afford smartphones or the data plans required to fully utilise their capabilities. Moreover, a lack of digital literacy can make it difficult for users to navigate the complex features of modern smartphones or access apps designed to assist with their specific needs. Finally, mobile interfaces are not always designed with accessibility in mind, creating additional obstacles for users with disabilities [46, 63].

2.3 Impact of Smartphones on Quality of Life

WHO defines Quality of Life (QoL) as an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns [48]. The WHO QoL (WHOQOL) Framework [48] covers the six domains: physical, psychological, level of independence, social relationships, environment, spirituality and personal beliefs. Prior research has explored QoL domains in different contexts, cultures, and lived experiences. For example, Schalock et al [61]'s widely-adopted framework on QoL of people with intellectual disabilities identifies eight domains, (1) personal development, (2) self-determination, (3) interpersonal relations, (4) social inclusion, (5) rights, (6) emotional wellbeing, (7) physical wellbeing, (8) material well-being. They also look at ecological perspectives [13], investigating the contributing factors to QoL at three different levels: (1) microsystem: the immediate social settings, such as family, home, peer group, and workplace, that directly affect the person's life, (2) mesosystem: the neighbourhood, community, service agencies, and organisations that directly affect the functioning of the microsystem, (3) macrosystem: the overarching pattern of culture, social-political trends, economic systems, and society-related factors that directly affects one's values, assumptions and the meaning of words and concepts.

Beyond smartphones, there is a general focus on AT use for functional improvements; it is often the psychosocial benefits – whether direct or indirect – that users find equally, if not more, meaningful [5, 6, 41, 42, 53, 57]. For many AT users, and in line with frameworks such as the ICF and the WHOQOL [48], the ability to feel autonomous, to maintain social relationships, and to participate meaningfully in society is central to their QoL and wellbeing. Importantly, the potential impact of AT extends beyond the individual user to the wider community and society. Increased employment opportunities, reduced dependency on caregivers, and lower healthcare costs are among the socioeconomical benefits associated with AT use [2, 49]. However, while existing evaluations of the economic impact of AT account for quantitative metrics such as cost savings and reduced caregiving hours, they do not include psychosocial outcomes, which, although challenging to quantify, are crucial to capture the full value of AT [27]. This limitation can result in an underestimation of the benefits of AT and contribute to chronic underinvestment in this area, disproportionately affecting people living in low and middle-income countries and exacerbating pre-existing health, social, and economic inequalities [31, 45].

Although research on smartphones and their use as AT has been growing, the existing evidence fails to produce a comprehensive understanding of the impact of smartphones as assistive technologies on the QoL of BPS and DHH individuals in LMICs, accounting for both positive and negative aspects. In this paper, we present the first longitudinal mixed-methods study investigating the impact of smartphone use on the QoL of BPS and DHH individuals in Kenya.

3 Method

This study used a mixed-methods research design that combined quantitative and qualitative approaches to comprehensively assess the impact of smartphones as assistive technology for BPS and DHH individuals in Kenya. The mixed-methods approach was chosen to capture both measurable changes in participants' experiences and the nuanced, lived realities of their interactions with mobile technology. The quantitative component involved a baseline and a follow up survey, while the qualitative component involved in-depth semi-structured interviews. This combination allowed for data triangulation, enhancing the validity and reliability of the findings.

We included both BPS and DHH participants to explore cross-disability differences in smartphone use and impact. Although their accessibility needs differ, their shared experiences in navigating mobile technology in a low-resource setting offer a unique comparative lens.

3.1 Participants

Study participants were recruited through a local disabled people's organisation, Kilimanjaro Blind Trust Africa (KBTA), which facilitated the recruitment and screening of the participants. A purposive sampling approach was applied to include a diverse demographic range and equal representation of BPS and DHH participants.

3.1.1 Survey Respondents.
A total of 193 participants completed the baseline survey, with 126 (65.3%) responding to the exit survey. After filtering for participants who completed both surveys, 121 (62.8%) were included in the final analysis. Of these, 37% (n=45) were aged 25-29, followed by 24% (n=29) aged 18-24. The smallest group, 8.3% (n=10), were 45 years or older. Most participants had tertiary or university-level education (70.3%; n=85), followed by those with vocational training (19.8%; n=24), while a small portion (9.9%; n=12) had only secondary education. Regarding phone ownership, 82.6% (n=100) had smartphones, while 11.6% (n=14) owned basic phones. In terms of phone ownership duration, 40% (n=40) had owned a phone for two years or less, and 25% (n=25) had owned one for five or more years. Gender representation was nearly balanced, but more DHH participants completed the follow-up survey (n=72) than BPS participants (n=49) (see Table 1 for demographic details). Participation was voluntary, and no personal or identifiable information was collected to ensure confidentiality and encourage a high participation rate. All participants were adults over 20 years old and were fluent in Kiswahili, semi-fluent in English, and KSL (for DHH participants only).

3.1.2 Interview Participants.
Twelve participants (5 female, 7 male) were recruited from the study cohort to participate in semi-structured interviews. Of the 12 participants, six were BPS and six were DHH. Participants were aged between 21 and 56 years old (mean=31.24, SD=11.62). Five individuals (all DHH) were educated at the post-secondary certificate level, four (1 DHH, 3 BPS) had a two-year college diploma, and three (all BPS) had a university degree. All participants had used an Android-based smartphone prior to participating in the study.

3.2 Study Instruments and Procedure

This six-month study included quantitative and qualitative measures to assess the impact of digital skills training, reported in [26], and smartphone access on the digital literacy skills and mobile phone proficiency, as well as their overall quality of life. As illustrated in Figure 1, the study included a baseline survey at the beginning and a follow-up survey at the end of the study. A two-day digital skills training was also offered, after which the participants received Samsung A14 Android phones and a monthly 2GB mobile internet data. Semi-structured interviews were conducted with a purposive sample of study participants. This section describes the study instruments and the procedure in detail.

3.2.1 Baseline Survey and Follow-up Survey.
At the beginning of the study, a structured survey was conducted to assess the participants' baseline information, including digital skills, QoL, the use of and perceived need for assistive technology. The survey questions were available in English and Kiswahili for participants' convenience. The study ran for 6 months, after which the participants were asked to complete a follow-up survey. The survey combined several outcome measures, including:

- S1: Demographic questionnaire (DQ)
- S2: Self-reported need and use of AT (ATNU) adapted from WHO Rapid Assistive Technology Assessment (rATA) tool [67]
- S3: Smartphone expectations questionnaire (MPE)
- S4: Smartphone usage questionnaire (MPU) adapted from [58]
- S5: WHO quality of life questionnaire (QOL) [48]

3.2.2 Digital Skills Training and Smartphones.
Participants received a two-day digital skills training, as described [26], to ensure a relative baseline of digital literacy and smartphone proficiency for all participants. Participants also received Samsung A14 smartphones and 2GB of monthly internet data to ensure they had equal access and similar capacity to use the smartphones.

3.2.3 Semi-structured Interviews.
Six months after the baseline survey, in-depth interviews were conducted with a subset of 12 participants purposefully selected to represent diverse experiences within the larger sample. The semi-structured interviews allowed for flexibility in exploring participants' lived experiences while covering key topics such as the benefits and challenges of using smartphones, the impact on daily life, and suggestions for improving smartphone accessibility. The interviews were conducted in the participant's preferred language, including a mix of English and Kenyan Sign Language, and were conducted face to face in Kenya at the office of an organisation of disabled individuals. Each interview lasted between 45 minutes and one hour and was audio-recorded with participants' consent. The recordings were transcribed and anonymised prior to analysis.

4 Quantitative Analysis and Results

We conducted Wilcoxon signed-rank tests to identify significant differences between the baseline and follow-up survey results across two sections of the questionnaire: S4 (smartphone usage) and S5 (WHO quality of life). A total of 93 questions were analysed. The Wilcoxon signed-rank test was chosen because it allows the comparison of two related samples, in this case, the responses of the same participants, at the beginning and end of the study, without requiring assumptions about data normality. Additionally, Likert-scale data, which were used to measure participants' responses to the outcome measures mentioned in section 3.1.2, were quantified into ordinal values (e.g., 1 for "Very Dissatisfied" to 5 for "Very Satisfied"), making them particularly suitable for non-parametric analysis. Descriptive statistics, including medians, interquartile ranges, means, standard deviations, and percentages, were calculated to provide a detailed overview of the results. We also employed effect size r as a

Variable	**DHH**		**BPS**		**Total**	
	n	%	n	%	n	%
Gender						
Female	37	51.4	23	46.9	60	49.6
Male	35	48.6	26	54.1	61	50.4
Age Groups (in years)						
18 − 24	15	20.8	14	28.6	29	24.0
25 − 29	26	36.1	19	38.8	45	37.2
30 − 34	15	20.8	10	20.4	25	20.7
35 − 44	9	12.5	3	6.1	12	9.9
45+	7	9.7	3	6.1	10	8.3
Education level						
Primary	0	0.0	0	0.0	0	0.0
Secondary	11	15.3	1	2.1	12	9.9
Vocational	21	29.2	3	6.1	24	19.8
Tertiary/College	40	55.5	45	91.8	85	70.3
Type of phone owned						
Basic	8	11.3	6	12.2	14	11.6
Feature	3	4.2	2	4.1	5	4.1
Smartphone	59	83.1	41	83.7	100	82.6
Unknown/none	2	2.8	0	0.0	2	1.7
Duration of phone ownership (in years)						
<1	14	23.7	6	14.6	20	20.0
1 - 2	14	23.7	6	14.6	20	20.0
2 − 3	8	13.6	9	22.0	17	17.0
3 − 5	9	15.3	9	22.0	18	18.0
5	14	23.7	11	26.8	25	25.0

Table 1: Demographic Information of Survey Participants

PID	Age	Gender	Employment	Disability	Education	Previous Phone
D1	24	Female	Hairdresser	Hard of hearing	Certificate	Nokia (basic phone)
D2	28	Male	Carpenter	Hard of hearing	Certificate	Techno
D3	22	Female	Student	Hard of hearing	Diploma	Nokia (basic phone)
D4	25	Female	IT Job	Hard of hearing	Certificate	Samsung A02
D5	30	Female	Intern	Hard of hearing	Certificate	Techno
D6	54	Male	Comedian / sign language teacher	Deaf	Certificate	Techno spark 3 pro
B1	56	Male	Web Developer	Partially blind	Degree	Samsung A32
B2	21	Male	Student	Partially blind	Degree	Infinix
B3	26	Male	Content creator	Partially blind	Degree	Oppo A53
B4	40	Male	Business owner	Partially blind	Diploma	techno camon 15air
B5	24	Male	Musician	Totally blind	Diploma	Samsung A12
B6	25	Female	Student / Special needs teacher	Totally blind	Diploma	Samsung Galaxy A21

Table 2: Demographic information of interview participants

measure of the effect size to examine the strength of the differences between the two groups. Data were analysed using Stata SE Version 17.

4.1 Overview of the Combined Group Data

In the combined dataset, significant improvements were observed in 39 of the 55 questions assessing smartphone competence (71%), indicating that participants' digital skills improved markedly following the training session (Figure 3). The most notable advancements were in managing calendar functions ($Z = -7.732$, $p < 0.001$, $r = 0.737$), file management ($Z = -7.614$, $p < 0.001$, $r = 0.726$), and enabling/disabling accessibility settings ($Z = -8.278$, $p < 0.001$, $r = 0.782$), reflecting moderate to large enhancements in these specific competencies. Regarding smartphone usage patterns, 25

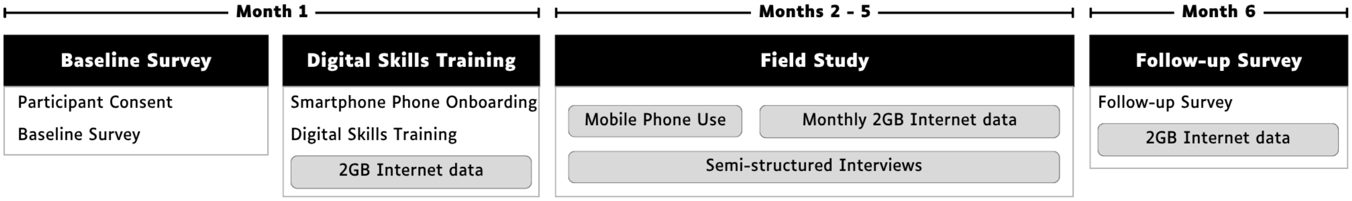

Figure 1: Study procedure showing key activities and milestones.

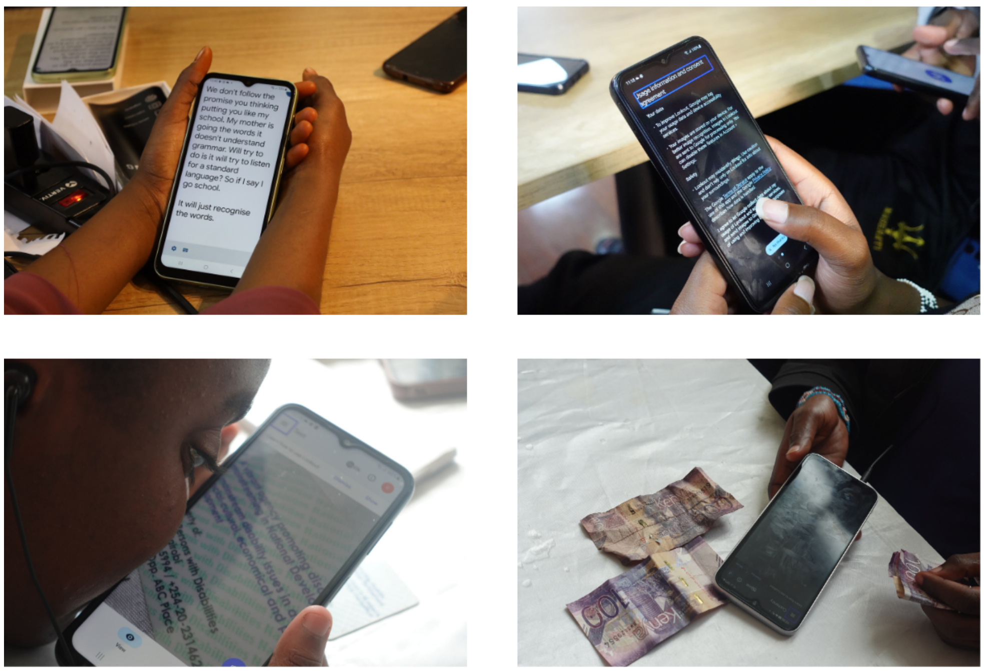

Figure 2: Research participants learning to use Android accessibility features Live Transcribe (top) and Lookout (bottom)

questions examined the frequency of activity of the participants, with increased participation in 10 activities. These included making or receiving voice calls, watching videos, communicating with organisations, travelling independently, organising and managing daily activities, accessing employment opportunities, and using healthcare services. The most significant improvement was observed in organising and managing daily activities ($Z = -7.238$, $p < 0.01$, $r = 0.693$). Furthermore, a substantial increase was observed in the use of accessibility features such as Live Transcribe ($Z = -6.425$, $p < 0.001$, $r = 0.823$), Sound Amplifier ($Z = -5.573$, $p < 0.001$, $r = 0.719$), and Live Captions ($Z = -5.936$, $p < 0.001$, $r = 0.748$). In the QoL domain, significant improvement was detected in access to information ($Z = -7.424$, $p < 0.001$, $r = 0.675$), reflecting a moderate effect size. Although other quality of life measures, such as concentration, leisure opportunities, and safety, did not demonstrate significant changes, participants reported notable increases in perceived helpfulness of accessibility features in their daily lives. Improvements were particularly evident for the Magnification Tool ($Z = -5.144$, $p < 0.01$, $r = 0.694$), Live Transcribe ($Z = -5.299$, $p < 0.01$, $r = 0.69$), Sound Amplifier ($Z = -4.858$, $p < 0.01$, $r = 0.649$), and Live Captions ($Z = -5.351$, $p < 0.01$, $r = 0.709$).

4.2 Improved Smartphone Competence Across Groups

Significant improvements in smartphone competency were observed between both groups. In the BPS group, 33 out of 50 questions (66%) showed significant improvement, while in the DHH group, 21 out of 51 questions (41%) demonstrated meaningful progress. For the BPS group, participants showed notable progress in turning on/off accessibility settings ($Z = -5.45$, $p < 0.01$, $r = 0.822$), navigating on-screen menus ($Z = -5.216$, $p < 0.01$, $r = 0.795$), and managing cloud storage services ($Z = -4.569$, $p < 0.01$, $r = 0.689$). These changes suggest a large effect size, indicating substantial gains in proficiency for managing device settings. Similarly, in the DHH group, there were improvements in making and receiving voice calls ($Z = -5.918$, $p < 0.001$, $r = 0.718$), navigating on-screen menus ($Z = -5.823$, $p < 0.05$, $r = 0.706$), and using Live Transcribe for conversation replies ($Z = -6.692$, $p < 0.001$, $r = 0.824$), again

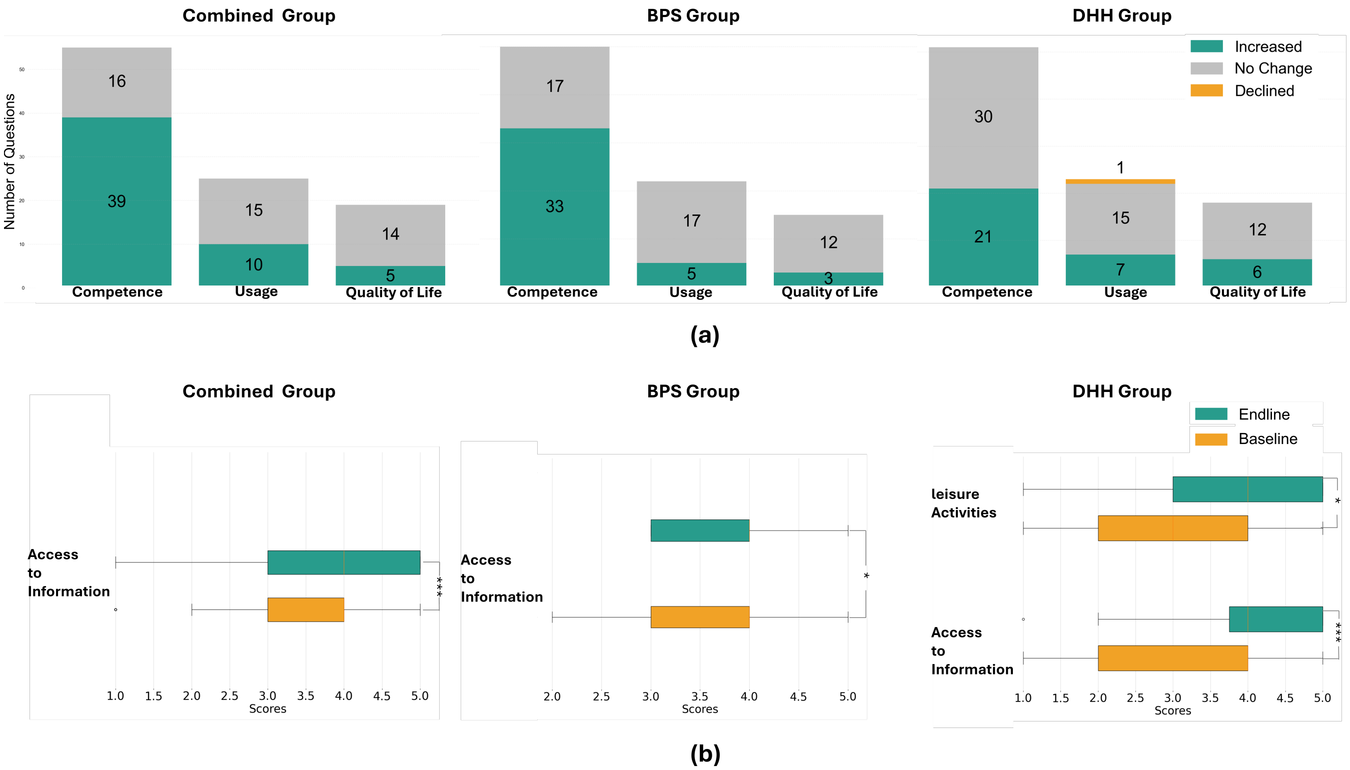

Figure 3: Results of Wilcoxon signed-rank tests for the combined group, BPS group, and DHH group across three topics: smartphone Competence, smartphone Usage, and Quality of Life. (a) The number of questions with significant changes in scores within each topic. (b) Wilcoxon signed-rank tests for the Quality of Life section are depicted. Lines beside the box plots indicate significance levels: $*p \leq 0.05$, $**p \leq 0.01$, $***p \leq 0.001$.

demonstrating moderate to large improvements in smartphone competence.

4.3 Quality of Life Improvements

Both groups reported significant improvements in quality of life, accompanied by notable advancements in accessing information for daily living. Participants in the BPS group demonstrated increased access to the information for daily living ($Z = -4.929$, $p < 0.05$, $r = 0.704$). However, no other quality-of-life measures showed significant changes in this group. In contrast, participants in the DHH group experienced significant improvements in accessing information for daily living ($Z = -5.584$, $p < 0.01$, $r = 0.658$) and leisure activities ($Z = -5.177$, $p < 0.05$, $r = 0.61$), also reflecting a moderate effect size.

5 Qualitative Analysis and Findings

The qualitative data from the interviews were analysed using a hybrid thematic analysis approach [12] informed by the research questions and data collection instruments presented in Section 3.2. The initial coding was done inductively by reading the interview transcripts line by line. Open-coding techniques were used to generate codes at the sentence and paragraph levels to extract meaningful insights from the interview data. The codes were then iterated and refined to combine similar codes and form sub-themes. For example, the codes 'sharing items on social networks to sell' and 'using WhatsApp to communicate with clients' were grouped into the subtheme 'Access to employment and business opportunities'.

Next, we used a hybrid approach to generate the high-level themes by organising related sub-themes and adapting Schalock's QoL dimensions [61]. Five co-authors, with expertise in qualitative research, reviewed the sub-theme categorisation during research team meetings and agreed on final three overarching themes: (1) Impact on Self, (2) Social Interaction and Inclusion, and (3) Impact on Material Well-being.

5.1 Theme 1: Impact on Self

This theme discusses the impact of smartphone use on identity and sense of self, encapsulating independence, agency, sense of ownership of the device and control over their activities, confidence and self-esteem, motivations and satisfaction with the phone use.

5.1.1 Increased independence and agency. Continued use of smartphone accessibility features allowed greater confidence in decision making about the support needed in different situations. For example, in some cases, DHH participants preferred to use the Live-Transcribe feature on their smartphones to participate in social

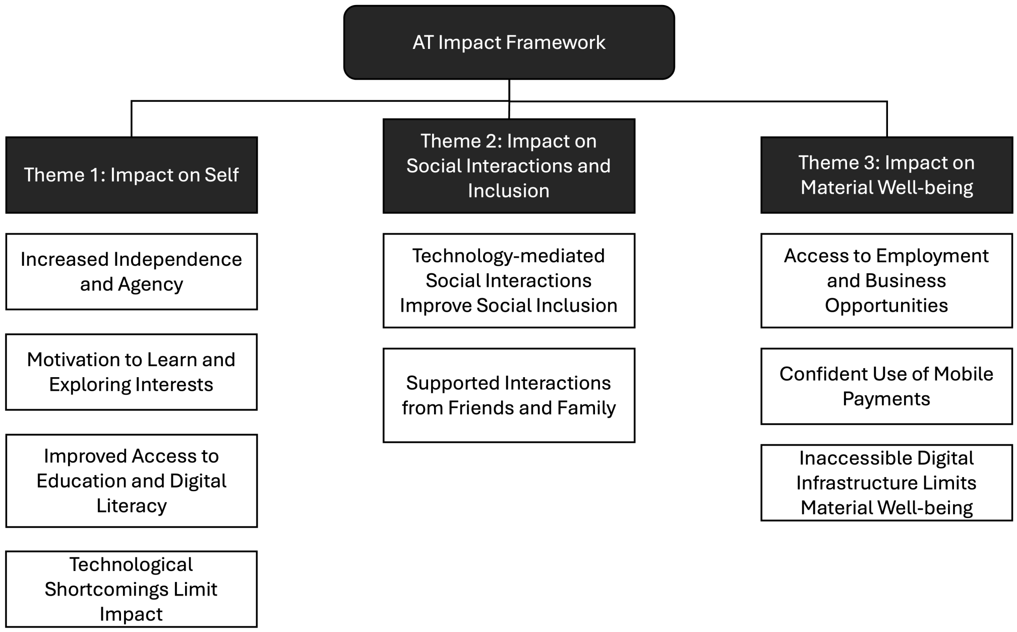

Figure 4: Overview of the top-level themes and sub-themes generated through thematic analysis

activities such as attending church without relying on a sign language interpreter, as noted by D6 — *"The skills that I acquired enable me. Before, I had no interpreter in church, but now, with the phone, I don't need one."* (D6) D1 also echoed this comment and shared their regular use of LiveTranscribe to participate in meetings and the profound impact it has on their self-esteem and independence, *"The phone has really changed my life. Number one, personally, as a deaf person, I am able to control many things independently; number two, I am able to attend meetings without a sign language interpreter. I think I have attended so many meetings whereby I don't need an interpreter, but I use live transcriptions."* (D1) They also added that the 'Sound Notification' feature allowed them to be more aware of their environment and be notified of sounds and respond without needing another person to support them, *"I am able to walk on the road independently. Sometimes in the deaf community, walking on the road here and there is not easy, but the phone is able to detect all the sounds. So it has created a very positive space for me within the environment that I work with."* (D1)

Aligning with the survey results highlighting a significant impact of smartphone use on activities of daily living, BPS participants reflected on their experience of using accessibility features and reported a positive impact on their independence and self-efficacy in many everyday tasks Particularly, Lookout, which uses the smartphone camera to identify objects and text in one's surroundings, was used by all BPS participants and enabled independence as it allowed them to navigate their environment, read documents and receipts and identify cash notes without needing assistance from a sighted person. For example, B4 noted, *"Sometimes when I'm home alone, I can turn on the Lookout and try to know what's around me. Secondly, if I want to read something, and I'm alone in the office, or at home, I can use it."* (B4) BPS participants also commented on the usability and effectiveness of the accessibility features like Lookout, delivering high impact and enhancing independence in their activities of daily living. For example, B2 said, *"I will call it [Lookout] my eye. Nowadays I don't have to go somewhere like "Can you help me know how this looks?" You can imagine like.... Simple things like reading a receipt, and you can do the text mode and read the receipt and know if I have been conned or if I have been given the right thing, so I would say in a week I use lookout... in fact daily at least 5-6 times."* (B2)

5.1.2 Motivation to learn and explore interests. Having an accessible smartphone also improved the participants' motivation to explore new interests and hobbies - as captured by D3 *"I'm motivated to learn more because, remember, when you read, when you learn, then your mental capacity is broadened, it grows."* (D3)

For example, two DHH participants mentioned searching for cooking videos on YouTube to improve their cooking and trying new recipes; D1 said, *"I want to go on YouTube and learn how I can be able to cook. I want to cook fish, and so on because they have their captions."* (D1). D5 also highlighted the limitation of LiveCaptions feature to certain languages, suggesting that, albeit the video allowed them to understand the steps of a recipe, LiveCaptions was not able to accurately translate and provide transcriptions for recipes in Hindi — *"Yes, I may find a recipe for 'Chapati'* [1] *the person might be an Indian, so I'm unable to hear the Indian language but from there, we are able to see the practical itself."* (D5).

Moreover, other DHH participants also articulated their use of smartphone applications and LiveCaptions feature alongwith

[1] means pancake or flatbread in Kiswahili

YouTube to improve their language skills. D3 described using generative AI-based conversation agents like ChatGPT to search for explanations and meaning of unfamiliar words, *"When I want to search for something, I don't understand a word, then I just write it on the app, it will give explanations very well."* (D3) Moreover, D1 also noted using similar smartphone apps to improve their writing skills — *"I am able to correct my English because you see when a deaf person wants to write something, they always have a challenge of writing in English. So, the AI is able to correct me so that I can be able to send my words."* (D1)

Although, participant appreciated how interacting with smartphone applications helped them to improve their English, they also desired a broader variety of supported languages. B2 also commented on the need to introduce local languages to make voice-based interactions easier for smartphone users whose first spoken language is not English, *"Maybe we can make it more juicy, like improving more languages, like why do I have to be using English to communicate with Google assistant? Make Kiswahili another option and speak to it in Kiswahili also."* (B2)

In addition to spoken languages, DHH participants were also motivated to improve their Kenyan Sign Language (KSL) skills through customised learning apps and YouTube videos combined with captions. P21 commented that there were many KSL learning apps available on PlayStore but many people in the deaf community were not aware of them. To improve the awareness about KSL, D4 highlighted the pervasive KSL content on YouTube which can help in improving KSL skills for the deaf community any everyone else — *"when somebody wants to learn sign language, I can tell them to use YouTube to learn I can also learn skills from trainers on YouTube."* (D4)

5.1.3 Improved Access to education and digital literacy. All participants reported a positive impact of access to information and educational materials using their smartphones. Although multilingual communication was a barrier for DHH participants, the majority of the participants found access to information and information sharing beneficial. For example, D3 mentioned being able to access course content shared online, *"when the teacher sent questions or documents online, I could be able to read or sometimes I could use Google or the same AI tool, app."* (D3). D4 also added that being able to search for topics online and store documents and books on their phone eliminated the need for carrying physical books — *"I can Google many subjects and learn using Google Apps. And also, I don't have to carry books. I can just use an online book and read."* (D4)

BPS participants also recalled similar experiences of accessing online documents and books via educational platforms and WhatsApp. For example, B1 mentioned the impact of Talkback on their ability to access documents, *"TalkBack is a total transformation, and I would say."* (B1). B5 illustrated how their ability to use Google Assistant Talkback would benefit their education, *"I will just answer it very simply when browsing I am able to learn, and I can download quality material from the internet and from my friends, different notes I am able to download them even if it is from WhatsApp, I am able to download and read them through the Google assistive features, so I am benefiting from it academically."*(B5)

B3 also highlighted that online platforms like Coursera could be accessed on the phone, allowing to learn new skills and acquire new knowledge through access to content and using online libraries like Bookshare, *"I did a course in data entry online using the Coursera website. So, if you really want to improve your knowledge using these phones, you can do it. You can also read articles and novels; you can also get all materials online; there is a certain website called Bookshare. It is a whole library that has different books, so, when you sign into that library, you can read and gain knowledge."* (B3)

5.1.4 Technological shortcomings limit impact. Generally, participants reported a significant improvement in their independence, access to information, and motivation to learn, supported by smartphone use. However, delving deeper into their experiences, they reflected on the shortcomings of certain smartphone features and applications, partly due to a gap in digital skills but also due to a gap in the accessibility features. For example, multilingual support was a common pain point for many participants who had family members that did not speak English or Kiswahili. Additionally, Kiswahili being the official language and most widely used, the DHH participants were particularly interested in Kiswahili to English (and vice versa) translation. One surprising finding from the study was that DHH individuals are fluent in KSL and in English but have basic understanding of Kiswahili. Therefore, without an appropriate translation mechanism, DHH participants found it difficult to use the LiveTranscribe feature. Moreover, inaccurate transcription due to LiveTranscribe not being able to understand Kenyan English accent caused frustration for DHH participants.

Accessibility of smartphone features and apps was also a persistent challenge for BPS participants. While they felt confident in using accessibility features like TalkBack to navigate the phone and Google Assistant to perform Internet search and access smartphone features, two BPS participants found taking photos using the camera app challenging. As B6 noted, *"you want to take a picture of a place and you don't know how to position your camera because it will not tell you to either move it a little or it's here or whatever."* (B6) Moreover, BPS participants also found typing challenging as they struggled to locate the keyboard and correct buttons. As B4 noted, this had a significant impact on their productivity and ability to use the phone independently, *"Reading is easy, but typing is the only issue that I have. if I go to M-Pesa, when I want to type my PIN, it's quite difficult."* (B4). As a mitigation strategy, B4 opted to use the emoji keyboard as they found emojis easier to use and effective in capturing their responses, *"I've told you typing for me, it's an issue, but I use emojis most of the time. If someone can go through my WhatsApp group, I use emojis most of the time."* (B4)

5.2 Theme 2: Social Interaction and Inclusion

This theme explores the participants' interaction with their socio-cultural environment and the ways in which using the smartphone as an AT affected the way participants engaged with their friends and family, co-workers, and the wider community.

5.2.1 Technology-mediated social interactions improve social inclusion. One of the primary ways in which the smartphone enhanced social interaction and social inclusion is through more accessible communication methods. Several participants, particularly those who are DHH, highlighted the critical role of video calling via WhatsApp in improving communication in sign language. D2 emphasised the importance of video calling over text or SMS when interacting with deaf individuals, especially when communicating with people who are not fluent in written and spoken languages. They explained, *"I video call because that is the only way you are able to get the information that you want because some of them are illiterate, so not all of them are able to understand whatever that you say"* (D2). This underscores the need for communication tools that accommodate different levels of literacy, particularly in contexts where sign language is the primary mode of communication. Aligned with the quantitative results of our survey, D1 also added that the majority of deaf individuals in their social network prefer WhatsApp video calls over text-based communication due to the improvements in smartphone cameras and mobile internet bandwidth, allowing for better quality video calls and making it easier to communicate in KSL.

BPS participants also shared that TalkBack and voice notes on WhatsApp allow them to interact with friends and family and contribute to discussions in family WhatsApp groups, thus be equally involved in social interactions, which was something they were previously excluded from due to communication barriers. B5 noted, "I am able to contribute, I am able to chat there, I am able to pass information, I am able to be in oneness with them." (B5)

The reduced communication barriers also fostered a deeper connection with the family and allowed participants to be more responsible for the wellbeing of others. B1 commented that the accessibility features of the phone and ease of communication have enabled them to be better connected to their children and contribute to their care independently, something they weren't able to do before — *"First of all, I am a father of three children. They're in school, college. So you see, you're able to interact, call, share documents, pay their school fees, and send them money. Send them money and support them. We talk. If it is their mother, we are separated but yes, we basically talk, especially matters relating to the kids."* (B1)

5.2.2 Supported interactions from friends and family. Friends and family also played a key role in supplementing the social interaction to overcome the shortcomings of smartphone accessibility. Particularly, for a seamless two-way sign language to a non-English spoken language (such as Kiswahili), the DHH participants sought support from friends and family members. For example, D6 explained that communication with their mother, who does not speak or read English, can be difficult as the LiveTranscribe feature has limited capacity to voice Kiswahili. As a result, their son supports the interaction with his grandmother by interpreting from written English (or KSL) to spoken Kiswahili. *"My mother in the village is not able to understand English but now with me I can just open the live caption and it interpret for her. Now using the phone my son helps my mother who is his grandmother with the phone."* (D6) This finding aligns with the previous research [8] highlighting the important role of human support.

5.3 Theme 3: Impact on Material Well-being

5.3.1 Employment and Economic Participation. One of the main ways in which having a smartphone impacted the participants' quality of life was access to employment and business opportunities. This was particularly interesting due to their diverse professional backgrounds and requirements for material well-being. For example, not all participants were job seekers, but those interested in applying for jobs could do so. B3 described their experience as, *"The smartphone has really helped me in those areas, like sharing documents, sending CVs, maybe if you are applying for a job, it has really helped me in those areas."* (B3)

D3 commented that WhatsApp groups organised by disabled individuals to share employment opportunities with each other can be very helpful and increase opportunities to apply for jobs — *"I'm able to see opportunities online, for example, we have a disability group, so I'm able to catch information on where opportunities are and apply, so, like, for me, I've applied for four jobs."* (D3)

B3 also recognized the profound impact of the accessible smartphone on the independence and financial independence of BPS individuals by enabling them to travel independently and work remotely, *"so you can also pay matatu (bus), you can do everything, you can also work online with this phone, if you really want to get money online, you can also use it for some platforms like freelancing, you can still use the phone, yes."* (B3). They also suggested that accessible smartphones and digital platforms are not only crucial to formal work but also for casual remote work such as participating in online research and paid surveys, *"I couldn't do them before because I didn't have a good smartphone to help me maybe navigate through the websites, so, with this one now, I am able to work online and do surveys, and I am paid. I also downloaded the PayPal app and connected it to the websites that I work for. Also, I receive my payments and withdraw them from PayPal to M-Pesa."* (B3)

As a business owner, D2 reported on using social media and online job platforms like LinkedIn to showcase their work and items for sale and WhatsApp for communicating with clients — *"I think now it's easy to take photos and post them on my pages, it's easy to give a description of the item that I'm selling, if somebody's far, then I just use the phone to send them."* (D2) Whereas, D6 shared that they have used LiveTranscribe and Live Caption features as well as transcriptions on video meeting applications like Zoom to attend in-person and online video interviews without the need of a interpreter — *"Okay, having a phone is easier whenever I am searching for jobs at least through getting the means to apply or when we are having meetings through zoom meetings and I am not having an interpreter I can still sit for interview."* (D6) D1 also commented on the usability of being able to connect their hearing aids via Bluetooth to their smartphones to attend phone calls and receive notifications, which enables them to participate in online meetings more freely — *"sometimes I use my own hearing aid, which is a bit more advanced, that's how I am able to get the vibrations and understanding on it."* (D1)

5.3.2 Digital Financial Inclusion. Kenya has a burgeoning digital and mobile payments ecosystem, illustrated by the pervasive use of mobile payment services like M-Pesa. The M-Pesa mobile app allows users to deposit, withdraw, transfer money, and pay for goods and services and is highly prevalent throughout Kenya and Sub-Saharan Africa, as B31 described. *"M-Pesa, because of the transactions, you always use your phone on a daily basis"* (B31). As a result, it is imperative that the service is equally available and accessible to all so that individuals can make financial transactions independently. Unfortunately, as our BPS participants reported, M-Pesa access is limited for those who own a mobile phone without accessibility features. Therefore, without a smartphone with appropriate accessibility features (such as TalkBack), BPS individuals would have to rely on sighted friends and family members to make M-Pesa transactions on their behalf. However, having access to Talkback significantly increased the BPS participants' use of M-Pesa enabling them to make mobile payments. As noted by B1, *"I also use M-pesa a lot to buy data, buy airtime, save money, and all those things that people use Mpesa for, specifically, I use it in My Safaricom app. So, my Safaricom app is very handy in that I also use it to pay bills, like buying tokens for electricity, purchasing data plans, and making calling plans. Yeah, all those beautiful things I am able to do."* (B1)

Althoug accessing mobile payment was possible with a smartphone, it was not necessarily easy for people. B3 commented on the difficulty of navigating mobile payment apps menus using TalkBack, *"There are also some enabled menus that the Talk-back also fails to read, so maybe if improved, it can give us the best experience."* (B3) Moreover, B4 , who generally struggled with the onscreen keyboard, suggested alternative user interface designs, such as fingerprints or voice instruction to unlock the mobile payment app, *"It will be easier. Instead of putting my PIN, I can put my thumb. Or I can do speech, and it automatically activates the Mpesa."* (B4)

5.3.3 Digital Infrastructural Barriers. Digital accessibility should in theory ensure that all individuals, regardless of their disability, can access and use digital content and services. Unfortuanately, all BPS participants mentioned experiencing challenges when accessing websites and smartphone apps using TalkBack. The lack of accessible design suitable for screen readers prevented BPS individuals from accessing online services. As described by B1, *"You find that using TalkBack, there are some things that are not really accessible, maybe like online you go, you find that you are filling in a form, an online form and maybe you need to select something like a date but instead of typing in the date, I am supposed to access the date picker, I am afraid this kind of situation is not accessible."* (B1)

B6 also highlighted the challenges BPS individuals, as screen reader users, experience due to inaccessible digital platforms and content. They emphasised the need for policies and standards to promote accessible digital services design to ensure equal access for everyone, despite their abilities — *"They [designers] just follow the policy because when you are creating a website, you are supposed to make it accessible even to screen readers and even people who are hard of hearing, you know. And even people who are limited to have colour contrast who can get seizures. And it's not good on image description. When you find an image, you try to tap so that the screen reader describes the image and then it doesn't."* (B6)

6 AT Impact Framework

The survey and interview findings demonstrate the substantial impact of smartphone use as AT across a range of QoL dimensions (presented above as themes). This impact is illustrated through increased confidence, agency, wellbeing, motivation to learn, and productivity. Importantly, the data reveal that this impact extends beyond the individual to the community and societal levels. For example, improved digital competence and smartphone-enabled independence supported more frequent and engaging social interactions and participation in leisure activities — an effect particularly strong for DHH participants. For BPS participants, improvements were especially notable in self-esteem, access to information, and overall life satisfaction.

In this section, we examine these results through the lens of Bronfenbrenner's ecological systems theory [13], which provides a valuable framework for understanding how individual behaviours, such as smartphone use, interact with and are shaped by their surrounding social environments. We also introduce the Assistive Technology Impact Framework (ATIF), a conceptual model derived from our empirical data that builds on and extends existing QoL frameworks [61].

While ATIF is inspired by Bronfenbrenner's ecological systems theory [13] and QoL frameworks such as WHOQOL [48] and Schalock et al.[61], its originality lies in grounding these theoretical lenses in empirical data from our longitudinal AT intervention in Kenya, and extending them to conceptualise mobile phones as assistive technology as a multi-level behavioural and ecosystem phenomenon — which builds on previous work such as Barbareschi's exploration of how mobile technology shapes and creates social infrastructure in informal settlements in Kenya [8]. Furthermore, ATIF bridges the gap between individual QoL outcomes and systemic ecosystem impact by integrating individual behaviours (e.g., use of LiveTranscribe) with structural ripple effects (e.g., reduced reliance on sign language interpreters, greater social inclusion, greater access to employment), offering a unified lens for understanding AT impact across micro, meso, and macro levels.

Grounded in our research findings, ATIF helps explain how mobile AT interventions - when combined with digital skills training - can result in cascading benefits across multiple layers of a person's environment. These findings reinforce the importance of viewing mobile AT not only as a set of tools for individual accommodation, but as enabling factors of systemic social inclusion and participation.

The ATIF framework consists of three interlinked domains (themes), structured across three ecological levels: Self (Microsystem), Community (Mesosystem), and Society (Macrosystem). These domains emerged inductively from our qualitative thematic analysis and were cross-validated through alignment with existing behavioural and QoL models.

At the **microsystem level (impact on self)**, ATIF captures how smartphone-enabled behaviours (e.g., using Lookout, TalkBack, Live Transcribe) support individual-level outcomes such as independence, agency, self-advocacy, privacy, and digital self-efficacy.

At the **mesosystem level (impact on community)**, the framework reflects changes in how participants interact with their immediate networks, including friends, family, workplaces, and peer groups. Participants reported increased social inclusion, participation in family and peer WhatsApp groups, and the ability to support others, which are critical to sustained adoption and peer reinforcement.

At the **macrosystem level (impact on society)**, ATIF captures how smartphones as AT combined with enhanced digital skills translate to civic participation, advocacy, economic opportunities, and interaction with institutional systems. Examples include the use of social media to advocate for disability rights, access to employment and business opportunities, and mobile payment and wider financial inclusion.

It should be noted that the framework is not static. The ripple effects observed in our findings demonstrate how behaviours initiated at the self-level propagate across social and structural domains, reinforcing a cycle of digital empowerment. In this sense, ATIF offers a tool not just for analysis, but also for guiding the design and evaluation of digital AT interventions.

In Table 3, we demonstrate through example participant quotes the impact of the positive behaviours enabled by mobile as AT on three levels: self, community, and society. The framework elaborates how a positive impact of AT enables self-determined behaviours which create a ripple effect on the individual's QoL, their community, and the society as a whole. We call this ripple effect 'waves of impact'.

The AT Impact Framework is offered as a tool to enhance the understanding of lived experiences of disabled individuals and the wider implications of smartphones as AT adoption and its impact on the QoL of the AT user and their wider ecosystem. Although developed through insight into the experiences of a small subset of BPS and DHH participants in Kenya, we believe the framework has wider applications and potential for generalisation to people with, and potentially without, disabilities globally.

7 Discussion

Our findings have highlighted several key insights on the use of smartphones as AT by participants in BPS and DHH. Although the research was conducted in Kenya, we offer these insights to inform wider application and future work across Sub-Saharan Africa and beyond. We discuss these implications in light of our findings and the existing literature below.

7.1 Applications of AT Impact Framework

The AT Impact framework provides a conceptual lens for evaluating and guiding the use of mobile phones as assistive technology across individual, community, and societal levels. ATIF's strength lies in its capability to map small shifts in behaviours, such as the use of screen readers, video calls, or AI-powered tools, and establish links with ripple effects that extend beyond the individual user and influence broader ecosystems.

As such, ATIF can be adopted and adapted to serve various purposes. Firstly, ATIF can be useful for AT designers and researchers in informing the design of smartphones as AT by understanding user behaviours and the impact of mobile AT interventions on these behaviours and the wider implications. As such, ATIF aligns well with existing human-centred and ability-based design systems [66], providing an additional layer of insight into the specific user behaviours enabled by digital AT interventions and their impact on the overall quality of life of the individual. Additionally, although not currently adopted in the ATIF, a temporal dimension can be added to not only evaluate the immediate impact at micro-, meso-, and macro-levels but also at various stages of technology adoption, providing a longitudinal perspective.

Secondly, governments, multilateral and humanitarian organisations can use ATIF as a monitoring and impact assessment tool to understand the large-scale impact of AT interventions on ecosystems, particularly focusing on the desired dimensions of quality of life, such as education, health or employment. Policymakers and regulators can adopt the ATIF framework as a comprehensive tool to monitor, evaluate, and refine national digital inclusion strategies, especially those that target people with disabilities. Traditional indicators of digital inclusion, such as device ownership, connectivity, or basic digital literacy, often do not capture the complex interplay between individual capability, social participation, and systemic accessibility. In contrast, ATIF's alignment with ecological systems theory allows for a multi-layered assessment that spans personal, interpersonal, and structural outcomes.

7.2 Implications for Technology and Policy Design

7.2.1 *Enforcing Digital Accessibility Standards.*

Access to smartphones as an AT can significantly enhance independence and communication for disabled individuals, but it only addresses part of the broader issue. The Disability Justice movement [3, 11, 14, 40] emphasises dismantling systematic barriers to achieve true equity and justice for full participation of disabled individuals in society. The lack of accessible digital systems and services undermines the citizenship rights of disabled individuals by restricting their ability to participate in activities that allow them to articulate their rights, such as voting or taking part in community meetings, as well as accessing essential services such as healthcare, education, employment, and government resources [5]. Furthermore, the United Nations Convention on the Rights of Persons with Disabilities (CRPD) and the United Nations Sustainable Development Goals (SDGs) emphasise equality in education and access to information and communication technologies to ensure the inclusion of people with disabilities in society. Despite many LMICs ratifying the CRPD and the SDGs [44], the implementation of policies and the enforcement of the digital accessibility standards are lacking.

As essential services like healthcare, banking and financial transactions, and education are increasingly being digitised, governments and mobile network regulators must ensure that digital services adhere to appropriate web content accessibility guidelines (WCAG) and universal design principles to ensure accessibility for disabled individuals.

7.2.2 *Adaptable User Interaction Design.*

Voice-based digital assistants hold great promise for enhancing the accessibility and independence of BPS individuals. However, the current technologies are limited in terms of language and accent diversity, presenting significant challenges for users in LMICs who are non-native English speakers. The leading voice-based assistants, such as Siri, Alexa, and Google Assistant, are designed primarily for native English speakers with common American and British accents in mind [50, 56, 68]. There is limited support for non-native English accents, leading users from regions such as Sub-Saharan Africa or South Asia to encounter difficulties in getting these technologies to accurately recognise and respond to their speech due to regional accents and dialect differences. Research has shown that voice recognition systems often struggle with accents and dialects that deviate from standard American or British English, leading to frustration and reduced usability for non-native English speakers or English speakers from other regions [7, 50, 56, 68]. As smartphones are becoming increasingly ubiquitous as AT in LMICs, it is essential

Participant statement	
If I am going to visit my mother, I just call her, mum I am coming, wait for me at this point or I will just come to where you are. So now that, it helps a little bit, because maybe previously, she would maybe come for me, or maybe if I am with her, I'll now be asking my mother, now mum, someone has texted me, I would like you to read for me, or if I am with the family or friends, please check for me this, please call for me this person, please do this, you know and it is a little bit easier, we know not everyone can understand, even if it is family, because they also have their lives. So with this, now we reduce that rubbing, that negative rubbing, yes. (B3)	Before I could not communicate with the phone because I knew nothing about the phone, but now I feel very comfortable. I can now communicate easier, meet friends and also learn more. Now, I am able to work on my own and not to depend on any other people; with everything I was taught, I am very comfortable. You know some people think that I am unable to work on my own, but they are now wondering if I can do very many things on my own, so that is a plus. Empowering the disabled people helps them, now that there are skills that are learnt they are able to know their value and also giving them confidence wherever they go. Because before they used to cry "help, help, help", but now with the empowerment they realise that things are easy after they get their skills from the training. (D6)
Behaviour	
Independent travel and social interaction	Independence in performing activities of daily living, improved social interaction, improved productivity
Impact on self (micro-level)	
Feeling more confident, improved self-esteem	Feeling empowered, enhanced self-efficacy, social connectedness
Impact on community (meso-level)	
Less dependency on friends and family, improved perception of people with disabilities, acceptability of assistive technologies	Changing perceptions of disability, opportunities for social interaction, positive attitude towards people with disabilities
Impact on society (macro-level)	
Breaking stereotypes about disability, improved social inclusion	Access to education and employment, Enhanced material well-being for people with disabilities, Inclusion of people with disabilities in the workforce

Table 3: Two participant statements showcasing the impact of mobile phone as AT on their QoL and the ripple effect on their community, and the wider society

that voice-based technologies are adaptive to the linguistic and cultural needs of users.

Current smartphone on-screen keyboards assume a certain level of motor skill and familiarity with touchscreen devices and are designed to perform different tasks based on the intensity and duration of the touch interaction. Therefore, adaptive interfaces are needed that can adapt to the sensitivity of the screen based on how the user applies force or offers visual or auditory feedback to help guide users in locating virtual keys. Touchscreen issues are not unique to BPS individuals but are certainly exacerbated due to the inaccuracy of non-visual touchscreen interactions. For example, [15] investigated the impact of fingernail length and found low comfort and efficiency with longer fingernail touchscreen use. Several studies have also [37] examined the implications of touchscreen design for people with limited fine motor skills and explored the design of unified [25] and adaptive user interface designs to reduce inaccuracies in touchscreen interactions [60]. In addition to adaptable software settings, low-cost alternatives such as CaseGuide [20] and 3D printed interfaces [69], which have been explored to improve touchscreen accessibility for BPS individuals, could also offer potential solutions.

7.3 Limitations

This study has some limitations that should be acknowledged and considered for future work. Firstly, the research was localised to Nairobi and surrounding counties in Kenya that have a higher level of education and employment compared to the rest of the country. This may limit the generalisability of the findings to a more diverse population of BPS and DHH individuals in the LMICs, particularly in relation to non-urban areas. Finally, there were some discrepancies between the survey results and the interview findings for the DHH group. Despite demonstrating a relatively positive outlook towards smartphone impact in the interview, the survey results were less significant. We concur that this effect could be due to several reasons. First, the six DHH participants who participated in the interview could have a positive bias towards smartphones due to their lived experiences and therefore gave the impression of a more positive impact that did not necessarily reflect the vision of the broader cohort. Second, DHH participants who completed the survey but did not participate in the interviews faced challenges in accurately answering the survey questions. While the research team assisted BPS participants in completing the surveys for their convenience, DHH participants completed the surveys on their own. It could be possible that the survey questions were not easily understood, which could have led to inaccurate responses. We recognise this as an important finding and suggest appropriate measures for future research to improve the accuracy of responses for long surveys.

8 Conclusion

Smartphones as assistive technology have the potential to create a transformative impact on the lives of disabled individuals. In this paper, we have presented a mixed-method longitudinal study that investigated the impact of smartphone access and training in digital skills on the QoL of BPS and DHH individuals. The results of the quantitative analysis revealed a significant impact on smartphone competence (both basic and accessibility features), as well as on certain aspects of QoL and communication preferences. Confirming these results, the qualitative findings also highlighted the transforming impact of smartphones on the participants' confidence and independence, social interactions, motivation to learn, and financial independence. The findings also emphasised the impact of smartphones as AT on the participants' community (friends and family) and the wider society. To highlight this significant insight, we presented the AT Impact Framework as a key contribution of this research.

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