Agency in Assistive Technology Adoption: Visual Impairment and Smartphone Use in Bangalore

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ABSTRACT

Studies on technology adoption typically assume that a user's perception of usability and usefulness of technology are central to its adoption. Specifically, in the case of accessibility and assistive technology, research has traditionally focused on the artifact rather than the individual, arguing that individual technologies fail or succeed based on their usability and fit for their users. Using a mixed-methods field study of smartphone adoption by 81 people with visual impairments in Bangalore, India, we argue that these positions are dated in the case of accessibility where a non-homogeneous population must adapt to technologies built for sighted people. We found that many users switch to smartphones despite their awareness of significant usability challenges with smartphones. We propose a nuanced understanding of perceived usefulness and actual usage based on *need*-related social and economic functions, which is an important step toward rethinking technology adoption for people with disabilities.

Author Keywords

Accessibility; India; Mobile Phones; Android; Bangalore; iOS

ACM Classification Keywords

H.5.m.: Miscellaneous. K.4.2 Social Issues: Assistive technologies

INTRODUCTION

Theories on technology adoption or acceptance among people with disabilities have for more than two decades been influenced by work on technology *abandonment*. Such work has at its center the technological artifact and the factors that impact its use, or more typically lack thereof. Outside the accessibility domain, work on technology adoption is largely dominated by *technology acceptance models* (TAM), which emerged out of management information systems (MIS) research. Unlike abandonment models, these models lay emphasis on the intrinsic and extrinsic factors that influence technology use.

In the last two decades, the line between technology designed specifically for people with disabilities — i.e. *assistive technology* (AT) — and mainstream technology is increasingly blurred. This is because devices built for mainstream markets have begun to support accessibility features that make them usable by people with disabilities. A prime example is the smartphone, which offers the capability of several AT devices or software that used to be separately purchased (e.g., screen readers, magnifiers, voice recorders). In addition, the app ecosystem supports a range of AT functions.

For blind users, adopting smartphones has meant adapting to the touchscreen interface, the app universe, and the use of internet services. Agency on the part of visually impaired mobile users to accept or reject this new model of mobile interaction is undercut by the fact that older keypad-based feature phones with separately installed AT software are being eased out of circulation [32].

Additionally, while a smartphone enables a range of digital services including access to media, location-based services, and online commerce, access to the full gamut of smartphone affordances depends in part on the network infrastructure, device capabilities, and individuals' ability to effectively navigate the interfaces. This has made technology adoption a moving target because the technology per se is part of an ecosystem of technologies, making it difficult to isolate the acceptance of one object of analysis away from a broader whole. Consequently, technology adoption research needs to go beyond solely whether or not individuals buy and use devices to understand the nuances of how people switch from devices and platforms.

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Using a survey of 81 mobile users with visual impairments in Bangalore, India, we show that an understanding of the functions that technologies enable, along with user experiences, helps create a more complete picture of technology adoption in accessibility settings. We present a description of what people use their mobile phones for, and how that differs across classes of devices that people can afford. We present qualitative data highlighting users' perspectives of the roles that mobile phones play in enabling and supporting various functions in their lives. Finally, we examine these data against the user experiences of things that do not work, to understand what people are willing to adapt and work around in the interest of maintaining their digital being.

We propose a move away from reductionist approaches (abandonment) and technology adoption models, which all suggest a binary answer to whether a technology is adopted or abandoned. Instead we argue that human agency may need to be understood within the necessity of adopting certain mainstream devices, such as mobile phones.

RELATED WORK

Management Information Systems Approaches to Technology Adoption

The technology acceptance model (TAM) [12] has been at the heart of an influential movement around thinking about the conditions under which individuals accept and continue to use information technology. TAM proposes two key constructs around factors influencing technology adoption. The first is "perceived usefulness," which is defined as "the degree to which a person believes that using a particular system would enhance his or her job performance" [12]. The second factor, "perceived ease of use," is defined as the "degree to which a person believes that using a particular system would be free of effort" [12, p. 320].

While previous research has focused on these two core constructs and their operationalization through questionnaires, subsequent refinements have examined other factors that influence adoption. These include motivation, which probes the extent to which a person desires to perform an activity as "it is perceived to be instrumental in achieving valued outcomes that are distinct from the activity itself, such as improved job performance, pay, or promotions." [13 p.1112] Motivations are seen either intrinsically (from one's own sense of value in a technology) or extrinsically (from the value attributed socially by its use) [13]. Other work has looked at the role of affect, which refers to the ways in which intrinsic emotions or feelings of gratification are invoked by the adoption or continued use of a technological artifact [35].

Synthesizing these and other constructs to study technology adoption, Venkatesh et al. [36] proposed the Unified Theory of Acceptance and Use of Technology (UTAUT), which puts forth four constructs, three of which examine use intent: performance expectancy, effort expectancy, and social influence; the fourth, facilitating conditions, is a determinant of use behavior. This work has been influential in business studies around technology adoption, and variants of the constructs have been used to examine technology adoption in organizational and industrial settings including banking [38], e-government [2], social media [11], and health records [4], as well as with specific population groups such as doctors [37], students [1], public relations professionals [3], veterans [8], and police officers [7]. Related strands of work include studies of the diffusion of innovations that take a macro view of which technologies do and don't make it in societies, and the various actors involved [31], and work on technology appropriation that goes beyond the idea of adoption to how people incorporate technology into their lives [5].

HCI Approaches to Technology Adoption in Accessibility

The traditional focus of technology adoption in accessibility research on abandonment has been attributed to a range of market and design factors [16, 29, 33]. Key among these has been a history of impairment-centric AT products that have found their way to users through innovators' desire to solve disability with technology or through welfare funding for accessibility, rather than as marketable products designed with user research [15, 28]. Kintsch and DePaula [20], proposing a framework for AT adoption, suggest four factors — the desire for changes in function, frustration tolerance, lack of stigma, and willingness to incorporate into daily routine — as factors in understanding individuals' abandonment behavior. More recent work has looked specifically at using TAM to frame the role of digital accessibility in the adoption of e-government and Section 508 guidelines [17]. Djamasbi et al. [14] proposed the extension of TAM to include information accessibility as a determinant of the traditionally used ease of use and usefulness metrics.

With the advent and widespread use of mobile devices with advanced capabilities, research started to examine smartphones as central to individuals' accessibility environments. Kane et al. [19], in their study of people with visual and motor disabilities, found that despite device inaccessibility, people adopted various strategies to adapt and use devices for their purposes. Work on web interfaces likewise showed that faced with inaccessible artifacts and digital information, users come up with a range of workarounds in adopting technology [6]. Yet, with increasing mobile penetration, the notion of AT as an irreplaceable artifact in one's daily functioning has made constant access to the mobile device critical [34].

At the device level, TAM-related research has suggested that the rapid adoption of smartphones in the mainstream market is explained through its confirmation of the model's ease of use and usefulness metrics [26, 27], as well as its fulfilling hedonic and utilitarian purposes [10]. Design research has likewise suggested the ease of visual swipe-based interactions [22]. However, for people with visual impairments the initial transition to smartphones was difficult until later innovations in tap and swipe functions made them more accessible [18].

Fears around the movement from keypad-based phones to touchscreen-based phones continue to be a deterrent to technology adoption [9]. Rodrigues et al. [30], conducting primary research in the wild, have shown that gaining proficiency in smartphone use is daunting a priori, and continues to present significant challenges in early use, leading to workarounds or limited use of device capabilities by users trying to stay within their comfort zone. These works bring to fore the centrality, and in many cases inevitability, of smart devices and their interfaces to our everyday experience.

Our work here deals with AT adoption in a Global South setting — where the comparative lack of access to resources, network infrastructure, and location-based services, as well as a lack of user-base for AT and the adoption of technologies typically designed for users in the West — creates an additional layer of challenges around the adoption and use for people with disabilities [23]. Related work on accessibility has studied smartphone adoption from the perspective of urban living, technical transition challenges, and community support for visually impaired smartphone users [25].

METHODOLOGY

Survey Instrument

We conducted a survey of 180 questions, administered to 81 respondents, along with a semi-structured interview with a subset of 26 respondents. Eleven follow-up interviews were conducted among 26 interviewees following the first analysis of transcripts, and the follow-up interviews focused on UX issues that were brought up during the first round of interviews. The research was conducted between July 2015 and April 2016 in Bangalore, starting with the surveys and followed by first- and second-round interviews. Because perceived usefulness — and specifically the income and economic participation within that concept — was part of our study, we restricted our sample to working-age adults. Respondent ages ranged from 21 years to 61 years (male μ=29, female μ=32). Two thirds of the sample was age 25–39 years. Table 1 describes the gender and device make-up of the interviewees and survey respondents. Table 2 describes the degree of vision impairment and length of smartphone use in the sample. Most respondents (88.9%) were employed. Top occupations were clerical (43.2%), executive (21.0%), teaching (11.1%), and tech (9.9%).

The 180 survey questions were divided into demographics, technology ownership and use history, affordance use, purchase behavior, repair behavior, transit behavior, AT comfort, and constructs (see Table 3).

The respondents for the first round were recruited through local disabled people's organizations (DPOs) and we thereafter worked outward by snowball sampling. All surveys and interviews were conducted using one of three languages — Kannada, English, or Tamil. All respondents were adults who were employed or actively seeking employment. Use of assistive technology such as a screen reader or magnifier on a mobile device was a prerequisite for participation in the study; therefore, we excluded anyone who did not use mobile phones or had only basic phones without AT installed. This in part explains the relative under-sampling of people who started using mobile phones within the last 5 years, who tend to be a younger or relatively lower-income populations using starter phones without AT capability.

Platform	Survey respondents		Interviewees	
	Male	Female	Male	Female
Android	24	14	7	10
iOS	9	2	5	1
Symbian	21	9	2	1
Other	1	1	0	0
Total	55	26	14	12

Table 1. Survey and Interview Sample Description by Platform

Top brands in our survey sample were Nokia (38.3%) Samsung (24.7%), Moto (14.8%), and Apple (13.6%). We classified the devices as smart/feature according to specifications on GSMArena. All primary devices, including feature phones, had internet capability. Besides phones, the commonly owned technologies among respondents were laptops (62%), desktops (47%), and voice recorders (21%). For interviews, we selected a subset of respondents from the survey sample to represent feature phones (3), low-end android (Pre-KitKat: 8), high-end android (9), and iOS (6) users. We oversampled users with newer phones because they had wider device experience and had dealt with multiple transitions.

Sight / **Years using mobile**	Moderate vision loss	Severe vision loss	Profound vision loss	No light percep-tion
0–5 years	1	3	3	1
5–10 years	7	12	23	14
>10 years	2	2	4	9

Table 2. Survey sample by sight and years using mobile phone

The vast majority (71) of surveyed individuals were legally blind (20/200+) and primarily used audio interfaces for managing the mobile interaction. Of 10 sampled individuals who had vision of up to 20/160 (moderate vision loss), 8 used a magnifier as their primary AT (Table 2). Of the total sample, 22 people (27%) had lost sight after age 10.

Constructs

The construct formation for our research was informed by the studies of technology adoption in MIS and HCI rather than a strict interpretation of TAM. The first set of constructs included derivatives of "perceived usefulness," using the UTAUT framework [36]. We operationalized elements of the social infrastructure that might provide facilitating conditions for technology use as well as direct intrinsic motivations around device use.

We gave users seven constructs in the survey to agree or disagree with on a Likert scale of 5, adapted from a questionnaire used in a global study of mobile use [23]. The questions were phrased as follows: "The mobile phone has increased my: (1) sense of independence, (2) safety, (3) productivity, (4) economic participation, (5) income, (6) social circle, and (7) mobility" (Table 3).

Construct	Explanation to respondent
Independence	Feeling of being able to manage one's own affairs
Safety	Feeling of physical safety during various activities
Economic participation	Feeling of being able to take part in activities like banking and shopping
Income	Earnings potential
Productivity	Feeling of mobiles increasing productivity at personal or professional endeavors
Social circle	Feeling of mobiles positively impacting one's size of social connections
Mobility	Feeling of being able to navigate public spaces

Table 3. Constructs for studying perceived usefulness

The second thread of technology-adoption-related survey questions was around usage, extending "perceived ease of use" constructs to include usability experiences. Here, we did not use TAM-based attitudinal questions; instead we measured people's actual use of various functions on their mobile devices such as music, radio, news, e-books, browsing, email, apps, camera, global positioning system (GPS), connecting to a computer, installing apps, using apps, social media, and camera. We created a construct, high-function mobile use (HFMU), which was a composite of all these, counting all respondents who counted more than six uses for their primary mobile device.

Qualitative research

Interviews lasted 30–60 minutes and were transcribed verbatim. The interviews were carried out by researchers who were also involved in the surveys, thus themes from the survey analysis played an important role in the direction of the interviews. Interview questions included descriptions of daily activities and technology use on mobile and desktop, purchase and device transition behavior, and descriptions of the impact of the mobile on constructs from Table 3. All interviews were allowed to thread based on topics that were interesting to us and we wished to probe further. All surveys and interviews were conducted in person by authors, and took place at respondents' homes or places of work. The interviews were used to provide in-depth descriptions of experiences and attitudes related to tech adoption. The interviews were open-coded by two researchers; the researchers conducted a second round of reading the transcripts to focus on usability discussions.

Limitations

We focused on people with access to mobile devices capable of AT, thus we over-sampled more affluent individuals within the population of people with visual impairments in Bangalore. With many TAM-related studies, analysis of perceived usefulness depends on Likert scale measurements of self-reported data on independence and economic participation, for example, and these self-reports might differ from individuals' actual behavior.

FINDINGS

Cost

We found that there is a fairly high cost associated with any technology switch because of the price of phones. People spend a reasonably high share of their monthly income on their mobile device, and this share increases for respondents in lower income brackets. Devices cost more than 70% of a family's pre-tax monthly household income (Table 4).

Income bracket [1]	Mean Cost of phone (US$)	Cost of device as share of monthly HH income	Cost of device as share of monthly personal income	Mean years using mobile device	Mean years using smart-phone
Low (13)	129.86_a (101.06)	$.71_a$ (.59)	$.71_a$ (.64)	7.00_a (2.73)	0.56 (.76)
Middle (38)	193.47_{ab} (137.85)	$.31_b$ (.23)	$.52_a$ (.42)	9.32_b (2.05)	1.4 (1.53)
High (15)	312.00_b (269.32)	$.15_b$ (.17)	$.42_a$ (.66)	9.40_b (2.54)	1.4 (1.27)
F	4.157**	11.062***	0.778	5.336***	2.049

Table 4. Cost of mobile devices by median household income of respondents. Standard deviations are in parentheses. ** = p < .05, *** = p < 0.01. Means that do not share subscripts differ by p < .05 according to Tukey's post-hoc test. *HH* household

With respect to cost of the phone as a share of monthly household income, there was a statistically significant difference between groups as determined by one-way analysis of variance (ANOVA): ($F(2,62) = 11.062$, $p < .001$). A Tukey post-hoc test revealed that the cost of a phone is statistically significantly higher for low-income respondents ($.71 \pm 0.59$) than middle-income ($.31 \pm .23$, $p < .001$) and high-income ($.15 \pm .17$, $p < .001$) respondents.

With respect to device longevity, we found that on average, people had used their most recent device for approximately 19 months, but there were significant differences between HFMU users (14 months) and non-HFMU users (19 months). We found a very significant difference in mean age of current device between smartphones (~13 months) and feature phones (~32 months). This is likely to be a result of the relatively recent shift to smartphones in India, but we can also conclude that users switching from feature

[1] Low-income defined as monthly household income of Rs. 20,000 (US$300) or less, middle-income as Rs. 20,000-100,000 and high income as over Rs. 100,000 monthly

phones were typically using their current devices to the end of their usable lives. In some cases, respondents reported replacing the external casings multiple times to keep a feature phone going. We found in our sample that almost all the used phones (9 of 10) were Nokia models with Talks installed.

We found that respondents with lower income were also less likely to cohabit with another significant wage-earner, thus earning a majority share of their household income. This made device purchase largely the financial responsibility of the individual with a disability. The data in Table 4 also show that on average, smartphones are relatively new in Bangalore, even though the vast majority of our respondents had spent 9 or more years using mobile devices. iOS users in our sample tended to be on average wealthier than those who opted for Android devices, who in turn tended to have higher household incomes than those who had mobile devices running on other platforms. Wealth also impacts individuals' technology environments — smartphone users were more likely to carry laptops than feature phone users, which suggests a greater physical contact with technology.

Respondents relied on others within the community of people with visual impairments for information on models, as well as second-hand devices. All 10 owners of used devices in our sample were male, reaffirming earlier research that showed men had better access to used phones because of their larger social networks, partly from fewer restrictions on their movements than women [24]. We also find that disabled persons' organizations (DPOs) and non-governmental organizations (NGOs) play a role in tech adoption because they had been a source of discounted bundled Talks software on Symbian phones and moreover played a role in encouraging people with visual impairments to use mobile technology by including AT-related subjects as part of technical training and independent-living sessions. With the integration of accessibility features into the device with smartphones, NGOs reduced their role in actual procurement but were still a source for tech support and offered introductory classes for Android and iOS for visually impaired users.

Perceived Usefulness

Using the constructs from Table 3, we examined perceived usefulness on social and economic metrics. When asked about perceived usefulness, respondents were told to evaluate impacts related to their current device; however, the influence of past and recent devices is potentially likely. All but one person in our smartphone sub-sample had owned a feature phone with separately installed AT. Smartphone users had a median of five past devices before their current one, whereas the median number of past mobile devices owned by a current feature phone user was 3.5. Smartphone users (66.0%). were significantly more likely than feature phone users (16.1%) to be HFMU; there were no gender differences.

Intrinsic Motivators: Social Functions

The UTAUT models cover some facets of facilitating conditions and social influences in understanding technology acceptance. Our questions around social usefulness interrogate four elements — mobility, social access, safety, and independence — in which the individual exerts different levels of direct control themselves, versus reliance on facilitating conditions in their social environments. For instance, on the function of social access, respondents report feeling relatively empowered to make new social media contacts and maintain casual connections through smartphones. On the other hand, physical mobility presents a function in which the facilitating conditions of the society around them — thus the physical infrastructure, reliance on sighted guides to access transportation, etc., are critical for access.

	Physical Mobility	Social circle	Safety	Indepe-ndence
Male (55)	42.33	41.41	37.82	41.60
Female (26)	38.19	40.13	47.73	39.73
Mann-Whitney U	642.0	692.5	540.0**	682.0
Smartphone(50)	36.96	40.99	40.63	43.47
Featurephone(31)	47.52	41.02	41.60	37.02
Mann-Whitney U	573.0**	774.5	756.5	651.5*
Non-HFMU (43)	42.62	42.35	44.00	38.81
HFMU (38)	39.16	39.47	37.61	43.47
Mann-Whitney U	747.0	759.0	688.0	723.0

Table 5. Survey and Interview Sample Description by Platform. Mann-Whitney test - individual cells report mean rank. * = $p < 0.1$, ** = $p< 0.05$, *** = $p< 0.01$

All four social metrics scored between *agree* and *strongly agree*, and independence ranked highest among all. Because the dependent variables were ordinal but not normally distributed, we compared mean ranks instead of means. The test indicated that the sense of safety attributed to mobiles was greater for females than for males ($U = 540.00$, $p < 0.05$). Additionally, people who kept a backup device reported higher impacts of safety and independence (.05%). Males (25.5%) and females (26.9%) were equally likely to have second devices, so the relationship between safety and independence held across gender. The second devices were typically used for two reasons — during device transitions, or as an emergency device. The most common backup mobile was a Nokia N series phone.

One apparently counter-intuitive finding is that the feature phone users perceived a greater sense of access to public spaces (mobility) than those using smartphones. We attribute this to the underwhelming transit-related affordances of smartphones in Bangalore, where GPS-based navigation on maps or rideshare applications do not work well as a result of technical and street-naming issues. On the other hand, the feature phones provide users with a basic but reliable tool for mobility — that of being able to call someone for directions.

Intrinsic Motivators: Economic Functions

Income consistently ranked lowest among all populations (and technology platforms) in terms of the mobile's perceived value. Income was the metric that people felt mobile phones gave them the least control over, because getting a job depended on extraneous factors such as employers' accessibility awareness (Table 6).

	Productivity	Economic participation	Income
Male (55)	42.11	45.43	43.14
Female (26)	38.65	38.65	36.48
Mann-Whitney U	654.00	471.50***	597.50*
Smartphone (50)	42.52	45.26	40.63
Feature phone (31)	38.55	34.13	41.60
Mann-Whitney U	699.00	562.00**	765.50
Non-HFMU (43)	39.19	30.83	42.77
HFMU (38)	43.05	52.51	39
Mann-Whitney U	739	379.50***	741.00

Table 6. Survey and Interview Sample Description by Platform. Mann-Whitney test. Individual cells report mean rank. * = $p < 0.1$, ** = $p < 0.05$, *** = $p < 0.01$

Economic effects are a significant part of TAM-related studies, particularly those that relate to individuals' sense of greater work productivity or ability to earn. In our survey, we probed both factors alongside economic participation, use of banking, and commerce. From among the economic factors related to adoption, we found that one, productivity, can be relatively more controlled by the individual, whereas economic participation and income require some form of extrinsic influence, such as investment into facilitating participation or access to jobs.

Some effects related to economic participation result from developments in recent years that allow for greater management of finances through smartphones. Independently accessing and managing banking prior to digital banking was a challenge for blind people, and even getting credit cards was difficult because of individual banks requiring physical signatures (despite no reserve bank stipulations) for account operation. Several respondents cited using or browsing FlipKart, a leading online marketplace, which prioritizes mobile devices as its primary sale platform and has been relatively accessible on the screen reader ShinePlus and iOS VoiceOver, and more recently on TalkBack.

We found that respondents consistently ranked productivity highest among economic benefits. People indicated they can better manage their processes and respond to communications because of the access to their mobile phones. In all settings, productivity's positive impact ranked between *agree* and *strongly agree*. Economic participation was rated highly overall, but there was much variation among groups (Table 6): men indicated more economic participation than women (Mann-Whitney U = 471.50, $p < 0.01$), smartphone users tended to rate economic participation higher than feature phone users (U = 562.00, $p < 0.01$), and those who have a high number of functions on their mobile phones tended to very significantly feel a higher sense of economic participation (U = 379.50, $p < 0.01$). In comparison, influence on income was rated poorly across all groups, with no group scoring significantly above a neutral rating.

To probe device attachment, we asked respondents to comment on how long they felt they could go without their mobile devices if needed. There was no difference on the self-perception of dependence on the device based on the number of years using a device, or based on gender. However, respondents who had high-function mobile use reported higher dependence ($p < .05$).

The perceived usefulness of the mobile device, however, showed no apparent impact on the use of the other main digital information device — the computer. First, while email and browser use were preferred on a desktop, social media were equally used on both platforms, and smartphone users were more likely to carry a laptop daily.

Usage

TAM frameworks, while helpful in understanding some of the broader social drivers of adoption, are less valuable with issues of actual usage and usability. Technology adoption studies in HCI are relevant in understanding what specific functions are being performed on the devices and how these differ across technologies.

Device capability and use

We found that technology adoption varies in terms of the number and extent of applications used, even within groups of respondents who used the same devices. We found, for instance, relatively high use of media such as books, radio, and music on feature phones and that these carried over to smartphones, suggesting that it is worth measuring entertainment as a perceived usefulness function. Table 7 shows that a majority of feature phone users used their phones for listening to and storing music. Several respondents reported challenges with media storage with moving to iOS (unfamiliarity with iTunes) and Android (naming structures for media files).

The use of internet-based services changed fundamentally once an individual switched to a smartphone. Even though the feature phones had browsers, email, and social media, we found that their rate of use rose with smartphones. While it is likely that there was an impact of early adopter behavior — i.e. individuals more likely to try new technologies move to smartphones first — interviews suggest that switching to smartphones was more related to regular phone update cycles than a desire to try something new.

Interviews revealed that the distinction between those who voluntarily adopt new technology and those for whom the switch is mandatory because of extraneous factors impacts attitude toward the new device, primarily in terms of fear of the interface and to some extent annoyance. However, our survey data show that there is no significant difference between device use among early smartphone adopters vs. more recent adopters.

When measuring the use of various functions on smartphones (Table 7), we were unable to measure whether access to other interfaces, specifically computers, impacted the adoption of these functions, because the overwhelming majority of our respondents (76) were also regular computer users. We also found no relationship between years of computer use with the number of functions used on a smartphone. For browsing, social media, and email, the three domains where it is possible to look comparably at which device is preferred, we found that email and browsing were used on both a desktop and the mobile. Here, the survey data were inconclusive on what was preferred (with the exception of Facebook, which was significantly preferred on desktop by regular users). However, the interview data offered us useful insights into the distinctions. Interviews revealed that smartphones were preferred for output, e.g., reading emails and basic browsing, whereas desktops were preferred for input such as composing emails and internet searches.

	Smartphone (50)		Feature phone (31)	
	Used at least once on current mobile	Used Daily	Used at least once on current mobile	Used daily
Email	41**	31***	5**	3***
Browser	36**	26**	11**	7**
Music	45	26	25	11
Radio	27	15	15	10
Books	18	8	11	6
WhatsApp	45***	39**	9***	8**
GPS	19	1	5	2
News	36	28	17	15
Games	8	3	2	0
Facebook	33***	22	9***	4
Twitter	9	1	2	1
LinkedIn	6	1	1	0
Chat Client	46***	38***	11***	8***
Audio Chat	39***	16**	7***	3**

Table 7. Survey and Interview Sample Description by Platform (significance within group of modality of use). * = p < 0.1, ** = p< 0.05, *** = p< 0.01

While our question on social circles in our examination of perceived usefulness showed no self-reported difference between smartphone and feature phone users, we found that WhatsApp and chat clients are by far the most widely used apps. Interviews suggested that access to social media like WhatsApp helped users maintain more regular contact with existing social networks rather than expanding into new networks. On the other hand, GPS-related use was extremely limited among study participants — only 1 of 19 smartphone users who had installed GPS used it regularly. GPS is a major draw for accessibility — navigation using a smartphone is among the commonly cited reasons for people wanting to adopt them — but respondents report that GPS is functionally unusable as a result of the poorly labeled streets, widespread use of informal landmarks, difficulties locating what side of the street one is on (a problem when boarding rideshare services), and general issues with audio output of location information. Device capability was also an issue because many users had phones with older versions of Android and had limited memory, with which data-heavy apps did not work.

In the past, at the very least one expected to pay about Rs. 9000 (~ US$150) for a feature phone with legal screen-reading software such as talks. Alternatively, people either purchased used phone or acquired pirated software, which could come with problems of its own. Typically, someone who used a used or low-end feature phone without legal software could for the cost of their old device upgrade to a basic Android with in-built, legal software. But the majority of the Android phones in the sub-US$100 range had less capacity, necessitating that users repeatedly delete apps (as voice-based apps and media take more memory) and clear cache, sometimes to where the phone was reduced to a voice-calling device because it was out of memory.

> *If a sighted person buys a phone, especially from a low-income group, he might possibly buy a phone that costs him say 2500 because Android phones pretty much start from 2500 to 3000. But the point there is people don't understand that correspondingly if you want to have a great deal of accessibility features in the phones it is definitely going to cost you more than 7500-8000.... See that used to be the problem with Microsoft. You have to invest on the laptop; on top of it, you have to invest on the screen reader. That is a pain, it's an absolute pain because you know we are talking about a section of the community which is sort of not economically that well off.*
>
> *Male, 42, journalist, iPhone 4S*

Usability adoption mismatch

We found that the basic TAM premise of ease of use aligning with whether a device gets adopted needs more nuance. Fears of adopting a touchscreen device were almost universally expressed in interviews about the initial move to smartphones; invariably the idea of a smartphone was used interchangeably with the idea of a touchscreen-only device. Interaction with touchscreens itself was not new — a third of the sample of non-smartphone users had some experience using touchscreens through access to others' devices or to hybrid touchscreen/keypad devices like Nokia N97. The real fear was about giving up keypad interaction entirely, even though we found that over time respondents preferred the smartphone and were highly likely to make it a primary device.

> *[The keypad phone] was quite easy to learn. I just needed to know basic key combinations — like the position of the Talks button, menu button, arrow keys, etc. — the rest was easy to learn. I don't think I had any kind of major*

> *difficulty that I could not solve on my own. Very rarely I had to take help from friends. In case of the touch phone, it was the reverse in the beginning. I needed help even to understand the screen and the location of icons on the screen. I had to take support from my friends and VI colleagues. … I have become more interested in technology after starting to use touch phone. Earlier my usage of the phone was limited to basic purposes like talking and messaging. I was using computer for sending emails or browsing the internet. After starting to use the smartphone, it has become very exciting. First, there are so many apps. I like checking out new apps and installing whatever I find to be very useful.*
>
> *Male, 28, clerical worker, Samsung Galaxy*

Technology adoption studies have also not adequately addressed users building redundancies into their technology environments. In interviews, respondents stated that unlike sighted mobile users in their networks, they did not swap SIM cards into new devices when they switched. Getting a new phone often meant getting a new SIM, typically with a prepaid connection, and continuing to operate the old one in case of failures. Users would eventually transition their contact information, but would expect to have a period, frequently several months, with two or more active devices. We had five respondents who (at the time of the research) still used a feature phone as their primary device, even after obtaining a smart device. But we also found that redundancies are generally built into all mobile use across the spectrum of phone users — those with feature phones were in fact even more likely to continue to have a second basic calling device. In interviews it emerged that Symbian-based devices had a reputation of crashing, thus having a failsafe device was a strategy that many respondents had internalized over time.

The difficulty of the initial adoption process aside, not a single one of our respondents had entirely abandoned the new smartphone after switching, although 10 of our 50 smartphone users continued to use a keypad phone daily. On average, they had been using the smartphone for 9 months while continuing to use another device. However, the usage findings in Table 7 suggest that applications that were already available on feature phones appear to be more used with smartphones. This suggests that adopting a smartphone makes the person do more with their devices over time.

The quality of use of certain affordances can change when moving from one interface to another. Social media, for instance, was commonly noted as a motivation for moving to smartphones. Yet the actual interaction on social media sites changed to more consumption than contribution after moving from feature phones to smartphones as users struggled with input. Tap-release and double-tap typing were challenging both in early adoption but also for more advanced touchscreen users, and voice typing was mostly untenable because of poor voice recognition. Editing mid-sentence on touchscreens was a common concern: The design of Android devices around Google meant that replicating contacts and drives posed usability concerns.

> *I could [add contacts] easily in the Nokia C5. I am finding it very difficult to [on Android]. First of all, opening contacts is a long procedure. First I have to open the apps folder, then the contacts folder, then I have to search for contacts and then type the name of the contact on the touch screen. Then I have to open the contact and read out the number…. Saving numbers is even more difficult. I have to type the number on the dial keyboard. This keyboard is very sensitive, even while dragging from key to key, numbers I don't wish to select also get selected. I have to keep checking in the edit box to see if the number is getting typed correctly … the entire number has to be typed again.*
>
> *Female, 30, clerical worker, Samsung J1*

Adapting to the visual optimization

When measuring perceived usefulness, it was difficult to construct means of estimating how people felt about interfaces that would evolve the needs of a user population different from themselves in needs and capabilities. The notion of control emerged in interview discussions around technology, and not just over specific interfaces but over the environment in which people operated.

Moving from Symbian-based devices to smartphones changed the support environment for users. The old environment relied on expertise with software such as Talks, which was internal to the community of people with visual impairments. DPOs and a community of well-connected AT users in Bangalore have traditionally provided tech support. With smartphones, we found that users take troubleshooting assistance from sighted users. Soft keypads present a number of problems, some of which require sighted intervention. An example is using interactive voice response (IVR) menus, which many users struggled with. Proximity sensors turn off the voice and deactivate the buttons on the screen, making it difficult for a blind person to navigate while trying to listen for IVR options and type on the soft keypad. Relying on the social grapevine or Google groups for tech support could offer solutions, but sometimes their complexity was such that reverting to a sighted intermediary was the only real option.

> *The technique is to use commas between numbers. It works like this: in the dial edit box, first enter the number that has to be called; follow the number with 10 – 15 commas without spaces (this is to bridge over the time taken by the IVR to read out the menu options); follow the comma with the number from the menu that has to be selected; follow again with 10 – 15 commas for the next menu – continue the process. I have used this technique to enter a call conference on Sabsebolo. It works, but it is very tedious. Also, this method can be used only on IVR menus where the options are already known; on fresh*

> *IVR numbers, this might take a number of attempts before the required section can be reached.*
>
> *Female 35, self-employed, Samsung Galaxy*

Sighted users have the option of switching to speakerphone mode with a soft keypad, which did not work for the respondents. There are several comparable examples. In our survey, we asked respondents for examples of technology or options they would have liked on their devices. We found that usable GPS is the single most desired, followed by keypads, optical character recognition, and better voice recognition. All of these capabilities were available in people's devices, but they were mostly unusable, mostly because of design choices that optimized the functions for sighted users. The issues noted with poor GPS could be mitigated by sighted users following the visual, turn-by-turn navigation despite the lack of street names, but this did not work for our respondents. With voice recognition, services in India are optimized for people who either can afford data or can be quick to switch between data and local WiFi, which respondents had trouble with because adding oneself to wireless networks is slower without a sighted interface.

> *I found that voice typing does not work if internet connectivity is not there because every time the voice needs to connect with Google for recognition. Since I don't have a regular net connection, I prefer to type and keep messages ready so they can be sent when connection resumes.*
>
> *Female, stenographer, Nokia N97*

Other challenges with adopting a primarily visual interface include managing media in folders, which for Android devices is again optimized for sighted users, who can recognize on thumbnails what a media item contains. Also, the range of bundled software typically sold on branded Android devices pushes ads that can be easy to get rid of for sighted users, but frequently cause unintended click-throughs for people using tap and swipe navigation.

Finally, relatively straightforward fixes that could be applied with minor setting changes are sometimes a source of prolonged annoyance. Visual-orientation settings like auto-switching screen orientation from portrait to landscape were a consistent problem, despite it being a relatively well-known problem that many users faced. Several respondents reported problems with monitoring battery usage and device memory, and reported referring to sighted intermediaries to help manage these.

DISCUSSION

Based on these findings, we suggest three enhancements to research in technology adoption related to accessibility.

First, AT adoption work in HCI has only recently started moving toward general-purpose devices after a longer history of examining technologies specifically designed for people with disabilities. The success or failure in the market of such devices depended on the uptake of one population — that of people with disabilities. This no longer applies. While this has been partially true with adoption of general-purpose devices like personal computers in the past, the focus of accessibility research there was generally on mediating the technology, such as the screen-reading environment, between the individual and the device. Smartphones represent a distinct problem in that they are part of the digital being of people and are central to a range of daily practices above and beyond communication and information access.

In MIS approaches to AT adoption, people's expectation of a technology being useful or easy to use is a central point of analysis. As we find here, the users of the feature phones rank the usefulness of their devices at par or higher than those who use smartphones, even though the smartphone users use their devices for a more varied set of tasks. Adoption of these devices or platforms by people with visual impairments is then moot — they have no choice. Rather, the new question becomes how people adapt, what they successfully adapt, and what they don't. More important, the new environment for mobiles is evolving to the needs and standards of sighted people.

There is scope to learn from both the MIS and HCI approaches: Kintsch and DePaula's [20] work on abandonment, which deals with factors like frustration tolerance and routinization, and work in TAM that seeks to understand extrinsic motivations in adopting a new technology. The case of GPS use provides us an example of this — the TAM models would suggest that the high demand for mapping and navigation services pushes up the perceived usefulness of the technology. We were often told by respondents that wayfinding was one of the main drivers of switching to smartphones However, we know from studying the user experience how and why GPS is not actionable, yet smartphones remain in use because GPS is only one among a range of services. Yet, to understand this in more granularity for what may make this untenable, we need to first identify GPS within the functional need for mobility, and understand that there are no other technological options for blind people — thus the failure of the device to provide this service does not push the user toward another device. The smartphone user defaults to the "feature phone way" of wayfinding — i.e. calling someone.

Second, we propose that in both the human–computer interaction and the management communities, technology adoption has been framed in binary terms. Technologies like mobile phones no longer allow for such analysis, because one would have to reframe the unit of analysis as the adoption of one or another specific element within the device rather than the device itself, which in turn may influence the decision to switch devices. To some extent, the flip side of this is also true, where the smartphone is seen as a single monolithic entity. While people do think of iOS devices as special and apart from the rest of the smartphone universe, those shifting from feature phones to basic Android devices often have expectations for the device based on hearsay on higher-end models that define what people think a smartphone can do. This frequently serves up a surprise to users who find out, for instance, that their in-built RAM is too small to support a range of apps. Here, we don't see any specific "inhibitor" to adoption per se; instead we find that the individual using a device with such restrictions functions at a lower level of capability because of a mismatch between their expectation of device affordances and what their device can actually do. This problem is arguably greater in the accessibility field because people don't have the same ability to test or research devices that sighted individuals may.

Technology adoption studies need to capture the functions that people use their devices for. We propose the functions — independence, safety, productivity, economic participation, income, social circle, and mobility — as useful metrics going forward because they allow a granular means of studying adoption and allow us to ask the right questions for deeper study. Here, for instance, we found that poor results on perceived usefulness function with regard to income can be studied through looking at social questions of labor market inequities for people with disabilities, whereas on perceived usefulness on productivity, a deeper user experience study into uses of input could be helpful.

Third, both bodies of work on technology adoption underestimate the role of social infrastructures. While Bangalore is a single case with its unique characteristics, the overarching structural factors found in our sample are relevant to other urban parts of the Global South as well. More than a third of our sample (25/81) first used assistive technology at a non-profit, which emphasizes both the lack of domestic resources to access AT and the important role that non-government actors play in people's access to technology, and as previous research has shown, elsewhere in low- and middle-income countries [21]. The result, however, is that DPOs have an vital role in enabling the choices that people make with regard to their technology use and access to maintenance infrastructures. In these, the function of access and repair are assisted if not regulated by the institutions that enable technology use.

CONCLUSION

In the last two decades work in CHI, especially HCI4D, has highlighted an increase in technology adoption challenges for various marginalized populations that may not have the agency to have their preferences represented in the technologies they eventually use. In this study, we argue that traditional studies of technology adoption have not adequately addressed several key elements that define the use of accessible technologies by people with disabilities, particularly in a Global South setting. Some of these, such as the imagination of adoption or abandonment as a binary, are high level, and others, such as specifics of input interfaces, are more specific to the daily experience of accessible technology use.

These frameworks do not consider the history of use, or a user's trajectory through various technologies. Nor for that matter do they consider adoption as an ever-evolving state. A crucial element of study is the issue of agency within technology adoption. For studies of technology adoption, the agency of the individual to choose to use a technology is an important defining element of its success or lack thereof. As more technologies become part of a daily environment of digital being, this may no longer be a choice.

The timing is important for accessibility studies because the smartphone ecosystems are evolving around a mainstream sighted paradigm. And yet, in parallel, the smartphone has the potential to be the primary gateway for visually impaired users to access the larger context of IOT devices, where accessibility through a smartphone app could be the only means of gaining independent access to all sorts of smart devices from washing machines to thermostats. These may seem a while away in parts of the Global South where a number of basic infrastructure challenges still exist, but getting the underlying systems right is important for a future in which access to similar technology moves towards greater affordability.

While much is known in HCI and MIS alike about assistive technology adoption and rejection, the extant knowledge is driven by our understanding of individual preferences and choices in largely non-mandatory technology use settings. Broadening adoption investigations to include functions of usefulness can help in understanding exactly where technology is working and where we need more effort. What matters in technology adoption then is not whether a technology is adopted, but rather how it is — and what that can tell designers and practitioners about the needs of users.

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