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Studying Personal Internet Access as an Infrastructure: A Qualitative Inquiry

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Internet access is often perceived and studied as a static phenomenon pertaining to a collection of connections and devices. To overcome some limitations of such an approach, this study examines Internet access as a dynamic phenomenon by conceptualizing it as an infrastructure. The study employs a theoretical framework of five attributes typical of infrastructures: invisibility, dependence on human practices, modularity, standardization, and momentum. Qualitative interview data were collected from British Internet users and analyzed to validate the infrastructural approach to studying Internet access. The results demonstrate that personal Internet access, studied as material artefacts and social practices surrounding them, is indeed characterized by five attributes of infrastructures. Conceptualizing Internet access as an infrastructure helps paint a more complete picture of complexities surrounding Internet access, encompassing its dynamics and the ways people experience, maintain, and develop it, and guides future research inquiry of its material dimensions and underlying social processes.

Keywords: digital divide, Internet access, digital inequalities, infrastructure studies, social shaping of technology, qualitative research, Internet use

It has been 25 years since the concept of the digital divide emerged, following a report by the U.S. National Telecommunications and Information Administration (NTIA, 1995) where the distinction between information communication technologies (ICT) "have" and "have-nots" was first addressed. Early research was mainly concerned with determinants of access to computers and the Internet, and studies showed that this was strongly related to sociodemographic factors such as age, income, education, and gender (Bonfadelli, 2002; De Haan, 2003; Katz & Aspden, 1997; Wellman & Haythornthwaite, 2002). However, as Internet penetration increased, the binary distinction between haves and have-nots was recognized as unnecessarily limiting (van Dijk, 2020). The term digital inequality was introduced as encompassing "not just differences in access, but also inequality *among* persons with formal access to the Internet" (DiMaggio & Hargittai, 2001, p. 1), and research focused on disparities in autonomy of use, support, skills, and scope of use, encompassing the second-level digital divide (Hargittai, 2002), as well as outcomes of online

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engagement, encompassing the third-level digital divide (van Deursen & Helsper, 2015). Taken together, scholars of the digital divide agree that access to technologies alone is insufficient for meaningful engagement with ICT and that digital inequalities exist in gradations rather than in dichotomous opposition (Livingstone & Helsper, 2007; Warschauer, 2003).

In digital inclusion research, the word *access* has been predominantly used to mean physical access to ICT, but scholars have warned against adopting a technodeterministic perspective where access is viewed as a primary indicator of digital inclusion rather than one of the factors that can either facilitate or impede meaningful online engagement (Helsper, 2012; Robinson et al., 2020). Moving beyond a dichotomous and static notion of Internet access is, however, characterized by several challenges related to conceptualization and operationalization of access, such as accounting for complex changes in access arrangements on an individual level, addressing the processes involved in developing and maintaining access, and accounting for a wide range of socioeconomic as well as sociocultural factors that may influence how people develop and relate to their Internet access. Previous research on the second-level digital divide provides considerable evidence about determinants of Internet access and their impact on patterns of online engagement. This research considers access in terms of locations of access (Blank, 2013; Hassani, 2006; Schradie, 2011), in terms of specific access arrangements, such as number of access points (Eynon & Helsper, 2015; Lee, Park, & Hwang, 2015; Livingstone & Helsper, 2007; Peter & Valkenburg, 2006), or in terms of different types of connections or devices used to go online (Correa, Pavez, & Contreras, 2020; Lee et al., 2015; Pavez & Correa, 2020; Pearce & Rice, 2013; van Deursen & van Dijk, 2019). Although this evidence is helpful in understanding specific material dimensions of Internet access, a holistic perspective encompassing material artefacts *and* social practices shaping it would help us better understand various complexities surrounding Internet access.

With a goal of providing a new angle for understanding Internet access and its role in digital inclusion, the purpose of this study is twofold. First, by suggesting how current understandings of Internet access could be further developed with concepts taken from infrastructure studies (Sandvig, 2013; Star & Bowker, 2006), this study aims to develop a conceptualization of Internet access that would account for its dynamic nature, which is crucially shaped by background social processes. Second, by providing qualitative empirical evidence supporting the proposed approach, this study aims to uncover the underlying mechanisms guiding development and maintenance of Internet access on an individual level.

Background

Access in Models of Digital Inequalities

Grounded in the knowledge gap premise, DiMaggio, Hargittai, Celeste, and Shafer (2004) place physical access as an intervening variable between an individual's characteristics and online engagement. Their conceptualization of access is static and focused on its material and technical aspects: (1) quality or adequacy of hardware, software, and Internet connections, and (2) location of access. Quality and location of access matter because they can impact upon the extent and favorableness of online engagement, opportunity for skills development, and, consequently, outcomes of Internet use (DiMaggio et al., 2004). Similarly, Helsper (2012) connects social stratification to the digital realm via links between social and digital

exclusion where access is positioned as a mediator between social and digital fields of exclusion, together with skills and attitudes. In discussing access, Helsper does not offer its definition but suggests that researchers should move beyond binary operationalization of access and examine its various dimensions, like quality, mobility, and ubiquity. Access at home, always-on, and broadband access are suggested as indicators of high-quality access, whereas the number of access platforms and their mobility are proposed as indicators of ubiquitous access. Both high-quality and ubiquity of access are expected to lead to a better online experience.

Taking a relational approach to digital inequalities, van Dijk (2020) uses the term "access to ICTs" as an umbrella term encompassing four types of successive kinds of access to ICTs: motivational, material, skills, and usage access. Theoretically, van Dijk (2020) distinguishes between: *physical access*, encompassing the opportunity to use digital media by obtaining them privately or publicly; *material access*, defined as "all means needed to maintain the use of digital media over time," including software, subscriptions, peripheral equipment, and so on; and *conditional access*, referring to "the provisory entry to particular applications, programs or contents" where the conditions are payment, membership or allowance (pp. 48–49). Increasingly, all three types of access are required for gaining full access to online content and services. van Dijk (2020) also differentiates between four characteristics of access: *technical capacity* of devices, software, and connections in the form of information-processing capacity and connection speed; *diversity*, referring to a great variety of Internet-enabled devices and applications ranging from basic to very advanced versions; *replacement*, where the transition to mobile devices and connections is most notable; and *technology maintenance*, encompassing instability of digital media, which often break down and have to be repaired and updated. Finally, van Dijk proposes that the four stages of access from motivation to material access, skills, and use are recursive and expected to return wholly or partially with technological innovations. This makes Internet access dynamic rather than static, and thus open to change. However, van Dijk says little about the processes underlying these dynamics, but his model suggests that they may revolve around the four characteristics of access.

Lastly, discussing access to ICTs, Selwyn (2004) differentiates between theoretical and effective access, where theoretical access encompasses a formal provision of access that is available to individuals in theory, and effective access refers to technologies that an individual feels able to use. Drawing on the work of Bourdieu, Selwyn (2004) suggests that what matters are "disparities in the context of ICT access," such as disparities in time, cost, and quality of technology (p. 347). Thus, "any realistic notion of access to ICT must be defined from the individual's perspective" (Selwyn, 2004, p. 347). In essence, Selwyn suggests that a move beyond the having or not-having conception of access should encompass a more complex notion of context of technology access. In doing so, he moves beyond objective material notions of access and suggests that an individual's own perceptions of access as shaped by their cultural and social capital should be considered as well.

Taken together, DiMaggio and colleagues (2004), Helsper (2012), and van Dijk (2020) all conceive of access as physical access to Internet-enabled devices and connections. By contrast, Selwyn (2004) introduces the notion of the context of ICT access but does not define it clearly. Following from largely material conceptualizations of access, the most thoroughly discussed aspects of access pertain to its material nature: quality, location, autonomy, ubiquity, and mobility. Relatedly, except from van Dijk (2020), all other

authors provide static accounts of Internet access. Though van Dijk (2020) allows for changes in material access driven by technological innovations, he does not elaborate on processes and outcomes of such change. Thus, I turn to infrastructure studies to propose another conceptualization of Internet access, one that accounts for its material dimension as well as social practices shaping it.

Internet Access as an Infrastructure

In digital divides research, the term infrastructure has been used primarily to refer to the purely technical facets of Internet access, such as equipment and Internet connections (e.g., Barzilai-Nahon, 2006; Dutton, Gillett, McKnight, & Peltu, 2004; Rogers, 2001). By contrast, infrastructure studies extend the "conventional understandings of infrastructure as 'tubes and wires'" to also incorporate organizations, individuals, their interrelations, and social practices (Bowker, Baker, Millerand, & Ribes, 2010, p. 98). Star and Ruhleder (1996) define infrastructure as "a fundamentally relational concept," where systems become infrastructures "in relation to organized practices" (p. 113). A relational approach to studying infrastructure brings the background processes and relationships into the foreground (Sandvig, 2013) and understands infrastructure as a relation, not as a set of things (Star & Bowker, 2006; Star & Ruhleder, 1996). Sandvig (2013) proposes that "thinking about infrastructure as a relation sensitizes the scholar to these multiple perspectives by asking to whom an infrastructure is addressed and, therefore, who is left out" (p. 92). Thus, to study infrastructures means to study relations among individual users, technological artefacts, and contexts.

Star and Ruhleder (1996) specify eight dimensions of infrastructures: embeddedness, tansparency, reach or scope, learned as part of membership, links with conventions of practice, embodiment of standards, built on an installed base, becomes visible upon breakdown. As such, infrastructures are "sunk" into other structures, social arrangements, and technologies; they do not need to be reinvented or built for each task, but support those tasks invisibly until a breakdown makes the system more visible. Infrastructures extend beyond a single event or practice, and both shape and are shaped by conventions and standards (Star & Ruhleder, 1996, p. 113). By drawing on the relational stream of infrastructure studies, Sandvig (2013) summarizes five attributes that all infrastructures are claimed to possess: (1) *invisibility*—infrastructure becomes apparent only when it breaks; (2) *dependence on human practices*—infrastructure is an arrangement of human practices and routines; (3) *modularity*—infrastructure is modular and incremental meaning that modifications of one part require adjustments to the others; (4) *standardization*—a component of infrastructure's invisibility that allows for interconnection with other systems; and (5) *momentum*—a system's inertia or particular trajectory. Sandvig (2013) suggests that these attributes can guide empirical investigation of the Internet as infrastructure.

Commonly, infrastructure scholars have examined large distributed systems, such as software supporting geographically dispersed collaborative work (Star & Ruhleder, 1996), global information-collecting systems (Bowker & Star, 1999), the Internet (Sandvig, 2013), or mobile networks (Farman, 2013). I propose taking a relational approach to understanding personal Internet access because it could be helpful in developing an understanding of how individuals develop, maintain, and use their Internet access. The proposed approach that focuses on the individual user tangents humanistic infrastructure studies, which "assumes the position that we live our infrastructures," views infrastructural objects from the

perspective of the user and examines "instances in which infrastructures become visible through qualities of their functionality" (Seberger & Bowker, 2020, p. 3). Personal Internet infrastructures could also be understood as "inverse infrastructures" that develop independently and are not centrally controlled, but are typically user-driven, self-organized, decentralized, and bottom-up (Egyedi, Mehos, & Vree, 2012). Examples of "inverse infrastructures" include citizens investing in community antennas or wireless networks, parents organizing neighborhood walking groups to and from school, and global user-driven initiatives such as Wikipedia. Although personal Internet infrastructures are linked to large-scale technical systems, such as infrastructures of Internet service providers (ISPs), they are owned and developed by individuals.

In defining personal Internet access infrastructure, I relate to Lievrouw and Livingstone's (2006) definition of new media that encompasses (1) the artefacts and devices, (2) the practices we engage in to develop and use these devices, and (3) the social arrangements that form around the devices and practices. As such, the study of new media originating from the social shaping paradigm (Lievrouw, 2006) parallels infrastructure studies insofar as its inquiry involves artefacts, practices, and social arrangements surrounding their adoption and use. Personal Internet access infrastructure is thus understood as a background foundation of material artefacts and social practices that support an individual's Internet use. Technologies in the forms of devices, their characteristics, and locations of access are still at its core. However, by extending the conceptualization of access to also encompass social practices and arrangements, access becomes dynamic and open to change.

Social practices involved in development, maintenance, and use of material artefacts involve the ways users relate to their access repertories and social arrangements that form around them. In the field of digital inclusion, there is no widely accepted framework for studying access dynamics. van Dijk (2020) comments on these dynamics in terms of technological developments in ICTs by suggesting technical capacity, diversity, replacement, and maintenance as their core characteristics. However, little is known about how user careers of ICT (Murdock, 2002b) are experienced on an individual level. Murdock (2002a) suggests that instead of a one-off study of access and use, "it would be more useful to track user careers over time, [. . .] identifying the dynamics that enable them to move on, or force them to remain in the same place or stop running altogether" (p. 388). There are many challenges involved in studying such dynamics, thus empirical evidence is scarce, with two recent exceptions.

First, Smith, Hewitt, and Skrbiš (2015) examined how and why diverse technology-related values and practices emerge among young people in the period between adolescence and early adulthood. Using qualitative interview data collected among young Australians, they found that the process of "digital socialization" is shaped by young people's access arrangements, where students who grew up with limited Internet access develop a task-oriented approach to technology use, whereas students who grew up with better and less regulated access value both educational and noneducational uses. Their findings highlight how social arrangements of access are involved in the development of value orientations and Internet use practices. Second, Gonzales (2016) proposes a technology maintenance theory depicting unstable access dynamics among U.S. low-income Internet users. These individuals struggle with sustaining access, resulting in limited engagement with health and employment information and biased attitudes toward technology. Gonzales argues that negative attitudes toward ICT reflect not only internal mindsets or feelings toward technology but also a rational response to disconnection and the costs associated with maintaining

access. She suggests that access inequalities are shifting from issues of ownership to issues of sustainability (Gonzales, 2016). This raises the question of whether similar dynamics can be observed in other populations. To contribute to this emerging line of research, I propose to approach the study of access dynamics by drawing on infrastructure studies. The aim of this study is therefore to explore whether the interrelationships between the material artefacts and social practices that shape access conform to the attributes of infrastructure defined by Sandvig (2013), and to shed light on the underlying processes that shape the development and maintenance of individual Internet access arrangements.

Methods

Semistructured interviews of 30–60 minutes were conducted with 29 participants. The interviews were undertaken in one large city in Scotland (20 participants; November 2014) and one large city in England (nine participants; January 2015). The target population were British Internet users aged 18 or above. The interviewees were selected through purposive sampling (Miles & Huberman, 1994). Several strategies were used to recruit participants: approaching people at random on streets, in cafés, and in public libraries, distributing flyers advertising the study in libraries and other public spaces across the cities, posting an ad on an online classified advertisement and community website Gumtree.com, using personal connections,[2] and snowballing. Participation was incentivized by £10 compensation in cash. The study obtained an ethical approval by the Central University Research Ethics Committee at the University of Oxford.

The average age of the participants was 38 years (range 19 to 62 years). In terms of income, 12 participants were in the lowest income group (up to £12,500 total pretax household income), six had £12,500 up to £30,000, and nine had a total pretax household income of £30,000 or more (two participants refused to state). In terms of educational attainment, three participants had no qualifications, nine had secondary education, seven had further, and nine had higher educational attainment. Looking at the economic activity status of the participants, 16 were employed, 11 were economically inactive, and two were graduate students. Finally, 13 participants had three or more Internet-enabled devices, 10 had two, and six had one Internet-enabled device.

All interviews were conducted face-to-face in public spaces, were recorded, and later transcribed. All names were changed to protect participant privacy. The data were stored and handled using NVivo software. Transcripts were critically read and analyzed. The coding was iterative, following Richards's (2009) "up from the data" (p. 73) and Saldaña's (2013) two cycles of coding approaches: The first cycle of coding involved a close reading of the data and writing analytic memos that formed the basis of the second cycle in which analytical coding was undertaken. Informed by previous digital inclusion research and infrastructure theories, some codes were developed deductively to capture concepts and processes relating to these theoretical propositions, whereas other codes were developed inductively from the ongoing reading of the data. To ensure credibility of the analytical process, multivocality was aimed for by including interviewees'

[2] Participants recruited through personal connections were second order connections and have never met the interviewer before.

multiple and varied voices through providing a thick description of their experiences, opinions, and personal significance (Tracy, 2010).

Results

Invisibility

The invisibility attribute of access came to the fore when interviewees discussed things that frustrate them about the Internet and when imagining how they would feel if they suddenly lost a connection or a specific device. The connection being down or slow was the most commonly expressed frustration, resulting in feelings of annoyance, anger, and impatience. These feelings were also related to feelings of dependency. While some interviewees expressed general feelings of dependency, others had specific ideas about how limited access would be experienced. These examples also illustrate instances where Internet access is infrastructural to specific activities, such as obtaining information. However, most took Internet access for granted. It is always in the background, and people become aware of it when connection is down or slow or when devices break, as illustrated in the following quotations: "I would feel I was kind of losing out. I really do feel I would be missing out on information" (Emily), and

> When I've got to get on [the Internet] and the connection is down. Or a certain website that you're wanting to go on it's like unable to access because it's down for maintenance or whatever . . . So that's the only kind of thing that really annoys me. (Anne)

> When you can't get a connection. That's probably the only thing, which is probably quite sad, because you're used to it being that fast, and you're used to always having it there, so when it's not there, you become a frantic maniac. (Alfie)

Dependence on Human Practices

Dependence on human practices pertains to the nontechnical part of an infrastructure manifested in practices and routines (Sandvig, 2013). Sandvig suggests that focusing on maintenance practices or practices that must be learned to use the infrastructure may be useful in understanding this attribute. To understand human practices that shape access infrastructure, interviewees were asked about episodes of adoption and maintenance of ICT. They reflect individuals' investment of social, personal, cultural, and economic resources (Helsper, 2012).

Social Resources

Social resources in the form of individuals' social networks greatly shaped development of access infrastructure, which was observable in three specific instances: (1) obtaining Internet-enabled devices; (2) enabling a home Internet connection and sharing devices; (3) providing support in terms of technical knowledge. Many interviewees explained how they got a specific device as a present from their families or friends. In some cases, respondents desired a specific device and they let others know about it, like Rose: "I've got it [a tablet] for my birthday and that's what I wanted of my husband."

For others, being given a new piece of technology was not something they wanted or felt they needed. Members of their social networks made that decision for them: "To be honest, my mum bought it [a tablet] for me, so I hadn't actually buy it myself. I wouldn't have actually bought it, if it wasn't bought for me" (Aiden). Whether or not respondents desired new technology had great implications for how devices were placed in the existing infrastructure. For example, Rose was really happy with her new device, which took on the role of a central device in her access infrastructure, whereas Aiden did not really find a role for his new tablet within his existing infrastructure.

Furthermore, members of social networks were sometimes integral in enabling interviewees' access to home Internet connections. This was especially important for unemployed respondents with low economic resources: "My brother and sister-in-law are paying for it for me in the house because I don't have enough money" (Olivia). "My neighbor has WiFi. She lets us use her WiFi. She just gave us her password and that" (James).

In this way, their access was shaped not only by their own resources and practices but also by those of their social networks. When people depend on others for Internet access, access to technology can be limited by the third party's daily routines, and changes in their life situations may result in access disruptions. For example, when Max's sister went to university, he lost access to a laptop: "Yeah, I used to use my sister's laptop, but then obviously, she goes to university, so she is quite busy with it. So, I am just stuck with my phone now."

The last theme that emerged in relation to social resources was the role of social networks in developing and maintaining interviewees' Internet access by helping them learn how to use technologies: "One of my other wee nieces had one [a tablet], my brother's girl, and she showed me all the basics on it, how to do, and how to take your pictures and how to upload things" (Rose). Getting help from their social networks was not always a one-off event but relevant throughout one's engagement with technologies. For example, some interviewees would rely on other people to perform activities they were not confident about, like online shopping: "If I need anything that I like on eBay I say my son [*sic*] to get it for me and I'll give him the money for it. But I don't order it myself" (Helen), and "I will go on for that [ordering cosmetics], but I always get my husband to do all that. I can't be bothered to go through the whole payment process, so I'll say to him: 'Just do that'" (Laura).

Personal Resources

Personal resources manifested in terms of skills and self-confidence in technology use, and these played an important role in respondents' engagement with access infrastructure. The level of confidence and technical knowledge affects how people develop and engage with their access in terms of what kind of devices they choose to buy and how they approach technology-related problems. Liz did not feel confident about using touch screens, so when talking about what her new mobile phone might be, she explained: "I wouldn't go iPhone or anything like that, because I've tried the touch screen phones, and all that swiping the screen and all that, it just goes all chaotic." More technical knowledge was desired by Aiden, who was explaining a network connection problem at work and how "if you've had just a bit more knowledge in computing you'd be able to fix it." Levels of technical ability also shaped

management of access infrastructure in a positive way. Thomas explained he did not need to upgrade his smartphone because he will

> download the stuff to a hard drive, if I can work out how to do it because Apple are quite good at stopping you doing anything like that. But, I usually find a way around it. If I can clear the memory out, I'll probably keep it [current smartphone] a little bit longer.

Cultural Resources

Cultural resources involved in the development of access concerned fitting in with the present technoculture. Selwyn (2004) argues this is achieved through "socialization into technology use and 'techno-culture' via techno-cultural goods" (p. 355). The importance of such socialization was expressed by many interviewees. Eva spoke about her mobile contract expiring soon and a desire to get the latest model smartphone because her current phone is "just embarrassing, because it's a rubbish phone and my friends . . . Not that I wanna give in to peer pressure, but you want something that looks nice." Alex, when asked whether he ever carried his tablet out and about, replied: "If it was an iPad, I would."

Overall, acquiring devices because they "look good" or are "up to date" or because "everybody has them now" was a significant theme, especially among young respondents. However, even Barbara, who was 48 and unemployed, had no formal qualifications, had only a smartphone for using the Internet, and used it mostly for visiting Facebook, told me she had just obtained a new-to-her, secondhand BlackBerry because "It's a more modern phone, so it's more updated."

These examples can also be understood in terms of relative digital exclusion. When individuals' family and friends move on in their technology use, some people think it is important for them to be able to follow, like Ethan:

> I couldn't actually keep in touch with friends, because they had moved on in their technology. I ended up getting very frustrated and think that I was missing out on things, because people had begun to use Facebook Messenger to organize meetings and drinks at the pub while they were on the go, and because I was still just using Facebook when I was on the computer, kind of in the evening, and I was getting this information too late. So, I was missing out on things. So, I just bought a new phone.

The above examples encompass practices of complying with an individual's reference group in terms of technology consumption. For some participants, being up to date with consumption of technologies was an important cultural resource, making them feel that they belonged to a particular group.

Economic Resources

Lastly, practices associated with access development and management largely depend on individuals' economic resources. Technology-related expenses usually guided decisions about infrastructure maintenance, and individuals' financial status is thus reflected in their access

infrastructure. Especially in low-income households, this resulted in broken or obsolete technologies not being replaced or Internet connections not being subscribed to: "No, the weans [children] broke it and I thought, too expensive to keep replacing it so you can just use the Internet so on your phones" (Liz on replacing her family's laptop), "As soon as I get a job, that [a new laptop] would be the first thing I'd put a wee bit money [sic] away for" (Liz on replacing her family's laptop), and "It's mainly the money, I've only just been able to afford to commit to a contract where I have to pay for it monthly" (Oliver on arranging a home broadband Internet connection).

Financial status also shaped daily routines related to the consumption of technologies. For example, a very general practice to save money was connecting smartphones to WiFi connections wherever possible and restricting usage of mobile data:[3] "I got the thing [an app] that shrinks my data usage when I'm out" (Jane).

Modularity

Modularity is understood in terms of interconnectedness. In relation to Internet access, modularity concerns relationships between different devices and connections. Discussions with the interviewees showed that modularity of access infrastructure is manifested in various ways. When describing devices in use in his household, Alfie noted:

> We've got tablets, mobile phones, laptops in the house. Um, we've got a smart TV, so there's Internet everywhere in our house and that's why we had to get fiber optics. We had to get a fast broadband to be able to cope with the demand, basically [laughter].

For Alfie, acquiring more and more Internet-enabled devices meant that his household needed to readjust the capabilities of its home Internet connection. A counterexample is Liz, who gave up her home Internet connection on realizing that the Internet can be accessed using mobile network data:

> Oh, it was in my house [a broadband Internet connection], my kids had been wantin' the Internet for stuff and I go to put on through the laptop, and then I discovered that you could use it through your phone, so I got rid of the Internet that I had in the house.

In contrast to Alfie, Liz was not able to afford to pay for multiple methods of getting online. After acquiring a mobile Internet connection and realizing that through a mobile hotspot her family members could connect all their devices, she decided to cancel the home broadband connection. Oliver and his girlfriend, however, did just the opposite but for the same reason, saving money. When Oliver started a

[3] In the UK, different types of pay-monthly contracts and pay-as-you-go options were available to consumers at the time of the interviews. In 2016, the proportion of tariffs that included less than 2GB of data per month was 33% (Ofcom, 2018). Pay-monthly contracts offered better value for money than pay-as-you-go options, yet older and less affluent consumers were more likely to be pay-as-you-go users (Ofcom, 2018). The practice outlined here would be more likely among users with pay-as-you-go or those with a small data allowance in their monthly packages.

broadband subscription and a WiFi box was installed in his home, his girlfriend's mobile data plan was changed: "Now she buys a cheap package each month, because we have Internet at home. So, when she leaves the home, she uses her [mobile] Internet, and when she comes home she turns her Internet off and uses the WiFi."

All three examples show that parts of access infrastructure are interconnected. A change in one part of infrastructure often gets reflected in another. Acquiring a new technology may interfere with individuals' daily use practices but also alter how the infrastructure at large is managed. Access is a dynamic entity where decisions related to one part get reflected in others, although they may not be directly related.

Standardization

Standardization allows infrastructure to connect with other systems. Discussions with the interviewees identified two ways in which standardization of Internet access is manifested. First, many participants explained how they connect their Internet-enabled devices to other technologies, such as televisions, portable speakers, or cameras. Usually, the process of connecting was perceived as easy and seamless:

> I have Chromecast on my iPad and if I want to watch a film, I just press the Chromecast and it goes up to my television [screen] because it is connected through the Internet and through my hub. So, and I can watch television, look at my pictures, play my videos. Anything like that! (Rose)

Most respondents who connected their Internet-enabled devices to other technologies did so to consume entertainment content such as music, movies, videos, and games. However, the ability to connect Internet-enabled devices to other systems, such as home appliances, was also important for efficiency and money-saving reasons. In such cases, personal Internet access becomes the infrastructure for household management. This relates to the emerging concept of the Internet of Things, which refers to connecting a plethora of smart devices to the Internet and to each other. Laura, who held rather negative views about the Internet, refused to use a smartphone and had not used the Internet much outside of work, stated:

> The one good thing that you can do on that phone [her daughter's smartphone] and my husband's work phone—we just had a new boiler and with that boiler comes an app called Hive. What it means is that you can be sat at work and from your phone you can switch the heating on, you can also control the heating, you can check any time and know what the temperature is in your house.

The second example of how standardization of access infrastructure enables users to connect to other systems is smartphones acting like hotspots. This allows individuals to get online by connecting a device to their smartphones or connecting through someone else's infrastructure. This attribute of access was used especially by those participants who were not able to afford a home broadband connection. Some interviewees cancelled their broadband connections at home when they realized that mobile hotspots can be used to connect other family members' devices:

> This phone can give out WiFi. So, we got rid of that [home broadband connection] and just use my phone to get Internet. You know, this was the first big phone that I got, and I had found that I had a thing called Hotspot. It takes the Internet that it gets and gives it out and you can use that Internet on your phone or on a computer, on anything. (Luke)

Momentum

Momentum is most typical of large-scale systems and systems of great complexity, but although personal access infrastructures are more agile, they do take on particular trajectories and are sometimes hard to restructure. The reasons for rigidity of access could be external, related to ways in which Internet companies operate. For example, Sam expressed his frustration over the inflexibility of ISPs. This was the main reason he did not have his own home broadband connection but was using and financially contributing to his neighbor's broadband plan:

> It's like, rented accommodation, so if I have to move, then I have to take it [Internet connection] with me; and I've done that before, and I've found it's a real pain trying to move your Internet connection. If you say, you know, "I only want it for a certain amount of time," they're like, "No, you have to have it for two years."

Another example of inflexibility pertains to mobile contracts that combine payment for a phone and network usage for a defined period. The contract cycle can determine respondents' decision to get a new phone:[4] "I'm on a sort of two-year contract on mobile phone. When the two-year contract came to an end a year ago, I upgraded to an iPhone5, which is what I use now" (Thomas).

Another important factor that shaped how access infrastructures' trajectories unfolded was the availability of financial resources that could be spent on technology. For most interviewees, buying a new laptop represented a substantial investment and was not something that could be done right when a need emerged. This meant that old computers that no longer worked properly kept being used. For Alfie's family, buying a new laptop was perceived as a substantial expense and a considerable amount of thought was given to the right time for replacing their "very old" laptop; he explained: "We kind of need a new one and we've been talking about it as, for example, a joint Christmas present for the house."

Taken together, the above examples demonstrate that access infrastructures are sometimes hard to change and take on particular trajectories, which do not necessarily correspond to users' idea of optimal Internet access.

[4] According to Ofcom (2018), in the UK, buying a mobile phone on a pay-monthly contract is a popular way for consumers to get a new mobile phone with their service. In 2017, around two-thirds of pay-monthly consumers used one of these plans, which provide a convenient way to pay for an expensive device in instalments during the contract period (Ofcom, 2018).

Discussion

Traditionally, Internet access has been conceived of as an indicator of digital inclusion to distinguish between those who do and those who do not use the Internet, and has been largely thought of in material terms by focusing on specific Internet technologies. To address the limitations of existing approaches to studying Internet access, I drew on infrastructure studies and defined Internet access infrastructure as a foundation of material artefacts and social practices that support individuals' Internet use. I argued that broadening the scope of Internet access beyond technical means may help us better understand its dynamics, related social practices, and their implications for digital inclusion. Such conceptualization of access has value for digital inclusion research because it helps structure research inquiry into specific material and social dimensions of access.

The findings presented in this study demonstrate that people's experiences of access correspond to all five attributes of infrastructures as defined by Sandvig (2013). By taking an infrastructural view of access, technologies and their associated social practices can be better understood holistically. Indeed, an infrastructural approach to access speaks to the notions of context of ICT access (Selwyn, 2004), technological careers (Murdock, 2002b), and users' autobiographies of technology use (Selwyn, Gorard, & Furlong, 2005). All of this suggests that access must be viewed as dynamic and social. Access is not just about devices and locations of use but also about how people experience it, extend it, reshape it, and connect it to other systems. In what follows, I will elaborate on these dynamics of access by looking at the five attributes of infrastructures that were examined in this study.

First, the attribute of invisibility showed that Internet access is often taken for granted. A parallel can be drawn here with Ling's (2012) concept of taken-for-grantedness, which describes the embedding of mobile communication in society as a social mediation tool that is part of the stable everyday routines. Similarly, Internet access is embedded in people's everyday routines and their social arrangements, and it invisibly supports their various actions. This is consistent with Star and Ruhleder's (1996) dimensions of embeddedness and transparency of infrastructures. Specifically, the set of technologies and practices that support users' online engagement is transparent and does not need to be reinvented or assembled for each task. However, Sandvig (2013) argues that invisibility is particularly tangible in the case of the Internet, "whose major physical parts are often literally invisible" (e.g., wireless signals, buried wires) as well as in the "web pages arriving as if by magic, relying on processes that are totally unknown and unquestioned by most Internet users" (p. 97). Indeed, this was evident among respondents who shared their frustration with slow or nonfunctioning connections. When people have difficulty gaining access, when equipment becomes obsolete or breaks down, access becomes visible—"visible upon breakdown" (Star & Ruhleder, 1996, p. 113). Such cases encourage conscious thinking about Internet access arrangements.

Second, by illustrating how access infrastructure depends on human practices arising from offline social, personal, cultural, and economic resources, I have demonstrated the link between offline resources and Internet access (Helsper, 2012). Previous research examining determinants of quality, ubiquity, or location of Internet access showed that these were mostly related to income, education, socioeconomic status, age, and the presence of children in the household (e.g., Eynon & Helsper, 2015; Gonzales, 2016; Hassani, 2006; Lee et al., 2015; Mossberger, Tolbert, & Hamilton, 2012). However, the results of this study

show that an interplay of different factors shapes how people arrange and relate to Internet access. Access infrastructure depends not only on an individual's knowledge of technologies, level of disposable income, and current living situation, but also on the actions and choices of others, as well as tacit norms about what is acceptable and appropriate within individuals' reference groups. Individuals' practices that shape access reflect a complex combination of different competing factors. For example, individuals experience tensions between the availability of financial resources and the types of technologies that are acceptable within their reference group, leading to specific access arrangements; or tensions between personal beliefs about technology and the actions of their family or friends, leading to the adoption of technologies even when they are not desired. These findings also suggest that what scholars of mobile communication have argued in relation to mobile phones—that they have "become an important part of identity formation and a tool for social stratification and integration" (Katz, 2007, p. 392)—can be extrapolated to the Internet access infrastructure as a whole.

The third and fourth attributes examined were modularity and standardization. The examples of respondents rearranging access (e.g., upgrading or canceling home broadband, changing mobile data plans) justify a holistic approach to Internet access, as changing one part often leads to changes in other parts of the access infrastructure. Moreover, personal access infrastructures relate to other systems and to other people's infrastructures. It is likely that with the rise of the Internet of Things, personal Internet infrastructures will become even larger and more complex. In this evolution, standardization will become more important. Egyedi (2014) argues that standardization, modularity, and interactive compatibility are strategies for creating system compatibility that is "crucial to sustainable system innovation" (p. 55). Compatibility of devices, connections, operating systems, and applications would enable smoother development of personal Internet infrastructures where individuals have various options in selecting what, when, where, and how to integrate new technologies (cf. Sahay, Aanestad, & Monteiro, 2009).

Fifth, interviewees' experiences reflected the momentum of access infrastructures. For most, a complete reorganization of their Internet access would be impossible. Apart from the availability of offline resources, infrastructure's inertia is also largely determined by the larger ecosystem of ISPs and mobile companies. An analogy could be made here with the concept of "integration" (Sahay et al., 2009, p. 399), where users need to integrate their personal access infrastructure with larger infrastructures of ISPs and other companies. Discussions with interviewees revealed the asymmetric power relations between individuals and companies, where individual users must coordinate with larger and more influential actors (Sahay et al., 2009). This factor of managing Internet access has been largely overlooked in the literature on digital inequalities and deserves future research attention.

Taken together, the results of this study inform research on digital inequalities in two ways. First, one explanatory value of the concept of infrastructure is to suggest ways in which the study of personal Internet access in relation to digital inequalities can move beyond binary and overly material approaches. Conceptualizing Internet access as infrastructure draws attention to the dynamics of access and the relationships between its various parts, individuals, and other systems. The five attributes can help guide the study of different dimensions of Internet access, such as: how people take access for granted and reconsider its provision when connectivity is interrupted or when devices break; how access is shaped by income, individual self-efficacy, the actions of family or friends, or technology-related developments in

individuals' reference groups; how the acquisition of a new device influences decisions related to existing devices and connections; how individuals use their mobile devices to use and control other devices; or what factors stimulate or impede the reorganization of access arrangements.

Second, throughout the analysis of infrastructure attributes, the relationship between individuals' sociodemographic characteristics and access infrastructures emerged several times, although this relationship was not the focus of the analysis. In general, this finding adds to the established relationship between social and digital exclusion (Helsper, 2012; Ragnedda, 2020). However, it also signals the importance of further exploring how "marginalized social groups are further discriminated with the rise of ICTs," which is because of "both macro and micro reasons" where "individual socio-economic inequalities, technological infrastructure and policy regulations influence the capacity to access and use ICTs" (Ragnedda, 2020, p. 42). Thus, it is particularly helpful to conceptualize Internet access as infrastructure, as it can help guide research on a complexity of factors that shape Internet access from different perspectives. For example, examining Internet access through the lens of infrastructural inversion could further reveal the relationships among different "components" of Internet access infrastructures (Morita, 2017, p. 740). Conceptualizing Internet access as infrastructure has proven to be a useful approach to understanding its complexity, which goes beyond the adoption or nonadoption of a particular device to encompass the ways in which people arrange and relate to different parts of it. Thus, this study offers a way forward in our understanding of Internet access in technologically advanced societies.

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