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This paper focuses on the technological barriers mobile knowledge workers contend with in their professional activities. In conducting an exploratory study of a small group, themes emerged regarding their technological barriers that eroded their capacity for mobility, which included interacting with associates remotely, incorporating mobile technologies into the suite of professional tools, and building a portfolio of applications and services that prioritized their efficiency. My analysis is developed from concepts in Ubiquitous Computing and sociotechnical theory. By analyzing their barriers and adoptive strategies, I suggest a framework that aims to identify barriers and associate them with solutions.

Headings:

Mobile Knowledge Work

Nomadic Work

Digital barriers

ICTs

Informal knowledge sharing

Communicative technologies

EXPLORING MOBILE KNOWLEDGE WORKERS' TECHNOLOGICAL BARRIERS AND ADOPTIVE STRATEGIES

by

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Introduction

> Well, you know, they have a lot more in terms of easier access. There is, for example, when I was in the New York office, there's a vending machine, where you can vend out gear, like a mouse, or an Ethernet cable for your MacBook, or a power supply for your MacBook. You just press a button like you're getting a Coke, only a piece of technology comes out. And so that's how they provision small stuff. So you don't have to go through IT to get like another cable.
>
> So they have access to that. I do not have a vending machine for technology in my office. So that was cool. But I actually haven't been there so I don't know. I'm assuming they have better internet connection. But otherwise, what's happened with technology is the stuff that used to be wildly expensive and really complicated—you had to be a major U.S. corporation to use it—is now down to the individual level, in terms of cost, in terms of ease of use, in terms of everything. So, that's what I take advantage of (P6).

This account describes a work situation relevant to whole class of knowledge professionals today. Like many fellow knowledge workers, this informant had turned nomad. Forgoing the diurnal engagements of the office, he plies his trade where convenient or necessary: at home, at coffee shops, at airports, and shared spaces, etc.

Knowledge workers constitute a rocketing class in the global workforce (Florida, 2002; Liegl, 2014). In fact, in the U.S. this class of workers has doubled in one generation, from 22 percent in 1960 to 43 percent in 2006 (Rainie & Wellman, 2012). This global phenomenon issues from an economic evolution where actors engage with commercial commodities on an abstract plane instead of concrete (Erickson, Jarrahi, Thomson, & Sawyer, 2013).

Moreover, the effects of the Great Recession and the expansion of the global economy have engendered modular and project-focused knowledge work models (Barley & Kunda, 2006; Herbsleb, 2007; Schultze & Boland, 2000).

Organizations and individuals have enacted work arrangements such as telecommuting, home-working, shared offices, hot-desking, global virtual team working and mobile working (Sørensen 2011). Generally, mobile knowledge workers are defined by work that is knowledge-intensive and mobile (Rainie & Wellmen, 2012). Primarily, they are a product of technological, social, and economic factors, as well as personal choice (Barley & Kunda, 2006; Herbsleb, 2007; Schultz & Boland). Their work spaces and projects may range spatially, temporally, and in clientele (Middleton, 2008; Su & Mark, 2008).

A critical factor for knowledge work mobility is use of technology, specifically information and communication technologies (ICTs). While this class may actively work while in a mobile state, their mobile flexibility is portrayed in their behavior as well as the technologies they employ (Davis, 2012). Integration of ICTs into knowledge work practice has changed its landscape (Jarrahi & Sawyer, 2013; Mazmanian, Orlikowski, & Yates, 2013), enabling flexible work practices and extended mobility among the knowledge workforce. Moreover, with the maturation of ICTs (Su & Mark, 2008; Cousins & Robey, 2005), a sociotechnical revolution has spawned a recognizable cadre of mobile knowledge workers: satellites orbiting spheres of both traditional and non-traditional entities of enterprise and commerce (Costas, 2013; Czarniawska, 2011; Jones, 2013).

Advancement in ICTs features and magnitude have not only given rise to this mobile knowledge workforce, but subsequently and successively shaped it. When examining the interplay of these technologies and the professionals who use them, they should not be viewed separate from past technologies used (Carroll, 2008) or from how users combine them with both complementary and dissimilar technologies. Instead, a holistic approach is needed, an underlying concept in what Carroll (2008) refers to as a technology portfolio, a metaphor of users' approach and interaction with ICTs stemming from their past experiences, evaluations, and impressions of contemporary technologies.

Furthermore, competition among technologies, enhancing their natural evolution, innovates them and affects users' impressions through experiences using them singly and collectively (Rogers, 1995). Innovations can serve to replace or displace, but also enhance use of technologies in a cluster (Shih & Venkatesh, 2004). It is the through the medium in which technologies can complement or clash that concerns their effectiveness when in active use (Vertesi, 2014), for it is the integration of ICTs that extend their usefulness and influence. Moreover, it is the synergistic effects between users and technology that extend their de facto effectiveness (Rossio, Bodgan, Severinson-Eklundh, 2014). While users may hope for interoperability, they are often faced with barriers that cause breakdowns, curbing operative intent.

Without the ubiquity of networked infrastructures today, mobile knowledge work would be impossible. But just as ICTs are enablers, they can also be disablers. When technological breakdowns occur, work is disturbed. Conceiving the dimensions of mobility, technology, and knowledge work as a reciprocally linked triad (Erickson, Jarrahi, Thomson, & Sawyer, 2014) significance of the interdependency among

knowledge creation and manipulation, technical acuity, and flexible mobility manifest themselves. Thus, knowledge is employed not just to one's work, but managing of work as well, reacting to or avoiding technological breakdowns. Consequently, the adaptive strategies that these workers employ determine their own operational effectiveness.

My research question entails the digital barriers existing in networked infrastructure that hamper mobile knowledge workers, and how they overcome these barriers by connecting technologies together. Peering through the lens of individual mobile knowledge workers' accounts of their technology use, their impressions, experiences of success or failure, and active use, we can identify infrastructural barriers mobile knowledge workers face. Employing the language of *seams* (Vertesi, 2014), which describes physical and digital connecting links and disconnects among layered infrastructures, I attempt to identify these barriers and along with them, the strategies that a contingent of mobile knowledge workers enact.

Literature Review

There has been a significant amount of research on mobile work and knowledge mobile work, particularly in the last two decades. What follows is a survey of the relevant literature, which explores the sociological, physical, and technical aspects of mobile-knowledge work practices.

(Mobile) Knowledge Workers

Several scholarship domains have defined knowledge work (e.g. information systems, information science, organization science, etc.). A collective conception of it

entails knowledge production and transmission drawing from intellectual and analytic acuity and theoretical and technical knowledge (Creplet, Dupouet, Kern, Mehmanpazir, & Munier, 2001; Davis, 2002; Schultze, 2000). Moreover, knowledge work entails not concrete but abstract work (Erickson, Jarrahi, Thomson, & Sawyer, 2013), what Rainie and Wellman (2013, p.173) describe as "atom" work and "bit" work, because knowledge workers interact with digital rather than physical artifacts. Davis (2002) emphasizes the dimension of "human mental work" while Erickson, et al. (2013) stress the "unpredictable" aspects of knowledge work that promotes novel approaches toward tasks and solutions.

Mobile work is not a new phenomenon. Historically, professions include sailors, drivers, pilots, postmen, etc. In the literature, the terms mobile and nomad are recurrent. According to de Carvalho (2009), mobility entails transporting work resources (i.e. devices, office artifacts, etc.) to generic spaces in order to get work done. Mobility is related to nomadicity: while similar, their differences are highlighted by Coilfi and de Carvalho (2014) in that the former entails movement across sites for work, while the latter's threshold for productivity is entrenched in greater complexity of resource use. However, they also detail information work as being primarily digital, and consequently, for mobile knowledge work, distinctions begin to blur.

Mobile knowledge work can be appropriately defined by its actors' professions and movement. As concerns movement, Underscoring the involved mobility, Su and Mark (2008) state that mobile knowledge workers regularly travel to meet with clients, vendors, and colleagues to conduct work knowledge-intensive work, while Dahlbom and Ljungberg (1998) contend that they may be on constant move with one work

environment, or engage in short or long travel. They have been defined as employees lacking a stable work environment (Rossitto and Eklundh (2007), as those with two or more work settings (Lilischkis 2003), as not location restricted (de Carvalho, Ciolfi, & Gray 2011) and as workers engaged in activity across diverse locations (de Carvalho (2009). They may be a part of an organization or be self-employed; professions include mathematicians, software engineers, computer scientists, economist, etc. (de Carvalho, et al., 2011), students, and Information Technology (IT) consultants (Carroll, 2008).

Among mobile environments, de Carvalho et al. claim that spaces are those chosen for productivity, convenience, tranquility, transportation. Rossitto (2008) highlights their fluidity, that they are successively designed and re-designed. Within the metaphor of actors on a stage, Su and Mark (2008) label mobile assets as actants. Yoo and Lyytinen (2005) underscores the lack of technological infrastructure in the setting. Perry et al. (2001) contend that mobile workers regulate their temporal and spatial access to information resources through mobile technologies, with which they can remove the uncertainty involved in contextual constraints.

Bridging the knowledge work and technology use with mobility, Erickson, Jarrahi, Thomson, and Sawyer (2013, p.2) conceptualize these workers based on three vocational attributes, embodied by "its bit-related, knowledge composition; its requisite mobility; and its infrastructural engagement." Indeed, they argue, their "singular expertise" in a knowledge domain prompts expanded engagement with associates, and it is at this convergence of specialization and mobilization, the authors contend, that boundary navigation occurs, temporal, spatial, organizational, infrastructural, social, and cultural.

Associated forms of boundary

Mobile knowledge workers confront various types of boundaries in their work: temporal, spatial, physical, digital, and social. It is these barriers than can cause personal and professional conflict, disrupting work flows and processes.

Considering spatial aspects, examining the properties of infrastructure help characterize its physical aspects. Star and Ruhleder (1996) listed 1) the embedding of structures, social arrangements, and technologies; 2) transparency, its ease of use in recurrent use; 3) scope, its use with a multiplicity of devices (e.g., such as use with WiFi); 4) learning through community of practice; 5) invisibility of services until breakdown. This is manifest in Perry's (2001) exploration of the differences between mobile and office workers: that the latter have a given familiarity and certainty with their work environment and physical, digital and human resources, around which they can structure their work with information and documents (2001). However, Mark & Su (2010) explain, some advantages are lessened by or nullified by the universality of systems and consequently their transferability among users.

Su & Mark (2008) add that the features of the portable office not only lack the traditional organization support structure, including human resources and office artifacts, but that artifacts must be carried from site to site, including portable printers, backup devices, batteries, SIM cards, and paper, and other supplies (Su & Mark, 2008). This speaks to the added work load in mobile working, with factors such as uncontrollable spatial situations and associated resource deprivation (Perry, 2007). Cousins and Robey (2005) posit that the operational complexities of working mobile give rise to conflicts with digital infrastructure.

Temporal dimensions of mobile work are commonly examined through specific structural properties, which allow delineation of a situation or event. According to Zerubavel (1981), these properties are 1) sequence, the order in which events typically occur; 2) duration of events or situations; 3) temporal location, the locations and sequence of events across time; and 4) rate of recurrence, suggesting patterns and cycles of activity. Using this framework, Lee & Liebenau (2000) posit that increasing deployment and adoption of technologies results in changes to this temporal order; moreover, they disrupt work flows (Rennecker and Godwin, 2005) and that they induce more rigid temporal patterns to organizations like universities (Pollock and Conrford (2004).

Advancing on the contextual dimension, Cousins and Robey (2005) ascribes mobile workers with multiple roles (e.g. CEO, mother, wife, club president) since they are not confined to specific time and space, and consequently may experience conflicts between personal and professional roles. Middleton (2007) notes that people have trouble disconnecting between personal and professional boundaries which ensues in conflicting roles. Prasopoulou (2006) studied how cell phones compared to landlines erode temporal and spatial boundaries and thus the workers' professional and personal lives.

Strategies for mobilization

Mobile workers adopt adaptations to the aforementioned barriers. Cousins and Robey (2005) explored the recursive work elements in mobile work, how people mobilize activity and strategize their time and resources in formulating work arrangements per locale, maintaining ties and project-coordination. Considering work spaces, Muhr (2012) shows how familiar places can return a sense of professional

identity while Liegl (2014) emphasizes the importance of the collective nature of social, technical, and atmospheric traits instills positive feelings or moods.

Solutions to temporal issues focuses on nomadic workers exhibitive traits of adaptive behaviors, given dynamic technological, individual and institutional environments. In managing information for the time and space of work they plan for temporal uncertainty and take advantage of down time (Perry et al., 2001). Because they align their work schedules based on past experiences, future projections, and, significantly, present dilemmas, they display diverse practices when engaged in the same technological and organizational environment (Cousins & Robey, 2005). Networking with clients is also important for a sense of identity and place within an organization (Perry et al., 2001), being bound to specific nodes of people and associated places.

Use of technology is very important in completing work. Erickson et al. (2014) argue that workers' technical acuity constitutes a module of their professional knowledge, and furthermore understanding how to use their technology is vital for planning and determining potential conflicts. Rossio et al. (2014) speak of a constellation of technologies created to complete a project. They posit that orchestration of a constellation of technologies within a group of users fosters mobility and work practice. Leveraging ICTs to complete work is the lifeblood of mobile knowledge work. ICTs empower people to control their mobility with provisions to perform daily tasks, fostering locational independence through robust communicative and information retrieval and processing power (Perry et al, 2001) and can foster work-life balance (Middleton, 2007).

Importance of ICTs in Mobilization

Several authors have examined the use of ICTs among mobile knowledge workers (e.g. Chen & Nath, 2005; Kleinrock, 1996; Kristensen, 2002; Kristoffersen & Lujungberg, I999; Lilischkis, 2003; Lyytinen & Yoo, 2002; Perry *et al.*, 2001; Su & Mark, 2008). Carroll (2008) explains the emergence of ICTs from Information Technology (IT) with an information systems shift that caters to mobile users, linking them with digital resources essentially communicatory in nature, notably social, personal, entertainment, education, and leisure.

Rossitto, Bogdan, & Severinson-Eklundh (2014) posit that mobile knowledge workers use a multiplicity of devices and Web resources. De Carvalho et al. (2011) listed considerations communicative features for collaboration, the latter feeding the need that these workers have for staying connected and preserving a community with associates. Technological multi-mediation of devices, platforms, and applications with cloud computing and Web 2.0 technologies (Bødker 2006), has provided expanded access to tools. Furthermore, portable ICTs endow autonomy and flexibility in (Kakihara & Sorensen, 2002) in establishing a fixed conduit with associates for immediate connectivity and communication (Arnold, 2003).

Laptops are the cornerstone of mobile knowledge work technology; they are key non-human actant for mobile knowledge workers, and may represent the office in its lead technological role in work assemblages (Su & Mark, 2008). Examples of handhelds include mobile phones (e.g. smart phones and feature phones) Personal Digital Assistants (PDAs), and mini tablets. These devices are ideal for diverse communication and immediate but minor tasks, due to their extreme portability, small display, and possibly

an onscreen keyboard; tasks may include short notes and voice memos, appointment maintenance, and access to easily digestible information (de Carvalho et al, 2011). Perry's (2007) found mobile phones as the primary tool for study participants.

Email allows workers spatial and temporal freedoms (Lawrence & Er, 2007; Rossitto & Eklundh, 2007), device independence, file-transfer, and access to ephemeral and long-lived information (de Carvalho et al, 2011). Phone and Voice over IP (VoIP) communication technologies are a form of synchronous communication, useful for conveying feeling and immediacy where email is insufficient (Su & Mark, 2008). Video Conference software enables virtual communication and collaboration, limiting travel needs to mobile workers, and conveys emotion better than voice-only communication (de Carvalho et al, 2011). Cloud storage is a relative late-comer to ICTs and has quickly become popular with advent of broadband connection, allowing large data storage and transference (Li, 2009).

Orlikowski and Iacono (2001), examining the treatment of IT artifacts in Information Systems literature from a ten-year period, found that the bulk of research concentrated on the use of a single technology platform. Wiberg (2012) has addressed the need for systems integration, emphasizing the necessity of concurrent interaction with multiple devices, applications, and platforms. In terms of resources selection and use, Carroll (2008) draws upon the temporal dimensions of human agency explored by earlier authors (e.g. Emirbayer and Mische, 1998; Rogers, 1995, Chae and Poole, 2005), contending that selection and use is tempered by past experience, the circumstances of the present, and future potentialities. She studied users' selection of their technological suite and concluded that users' preferences were guided by their temporal and spatial

circumstances, curiosity, information needs, need for control, and sensitivity to system shortcomings.

These technological suites enable a mobility that, at its best, manifests itself as Weiser's original vision of ubiquitous computing (Weiser, 1991; 1993), conceptually rooted in the idea of technological environments instilled with an invisible integration. In this scenario, users would not detect any gaps among systems, but instead they would enact seamlessness. Beyond this Sci-Fi illusion of seamlessness, other voices in Ubiquitous Computing address the constancy of seams in architecture. (Dourish & Bell). A few researchers have even embraced infrastructural heterogeneity and posit that users take advantage of them (e.g., see Chalmers and Galani 2004; Chalmers et al. 2005). This conceptualization, together with a gap in mobile-knowledge-worker research on information practices and technology use prompts a study of these workers using technology that is not illusionary, but real and actively used in concert within layers of infrastructures. By examining what technical barriers they face and how they contend with them, by strategizing and deploying ad hoc or recurrent solutions to work across seam in technology, is the goal of this research.

Analytical Framework

Several reasons led me to adopt the analytical framework and vocabulary espoused by Vertesi (2014) that she used to in a six-year study knowledge workers of two large-scale planetary science organizations. Through this analytical study, and importing vocabularies from Ubiquitous Computing, she constructed a vocabulary to describe both physical and digital infrastructural layers. Principally fundamental to my study is the concepts of heterogeneity, which describes the interplay of multiple technologies and

users, and the language of *seams,* a way to define the structural boundaries and overlaps among systems.

Vertesi (2014) builds on the studies in technoscience that examine the effects of infrastructure in knowledge production and practice. Her analysis penetrates the concepts of infrastructural inversion (Bowker, 1994), examining the roles that boundary objects, translation, trading zones play as users navigate through infrastructural domains (Star and Griesemer 1989; Galison 1997; Gieryn 1999).

In her analytical framework, Vertesi (2014) adopts two vocabularies: the first, heterogeneity: given the existence of multiple actors and systems, of diverse classification, "overlapping," each infrastructure or infrastructure layer supports, includes, or excludes features (p. 268). Second, from Ubiquitous Computing, the language of *seams,* fathered by sociotechnical visionary Mark Weiser. Weiser (1993) described this as "the nonintrusive availability of computers throughout the physical environment, virtually, if not effectively, invisible to the user" (p. 71). Vertesi (2014) claims, in the last two decades, as technology and its user have evolved, his vision of seamless integration among devices and digital space has begun to be realized. Indeed, "this language of seamlessness, invisibility, and non-intrusion" (p. 269) in HCI and systems design has instrumented system ecologies.

Vertesi (2014) claims that using the language of *seams, seamlessness,* and *seamfulness* highlights the integration and tensions among technological infrastructures. They "often collide: their seams are visible in their many edges, endings, and exclusions" (p. 269), so that systems are dispersed among infrastructural layers in implicit or explicit compatibility or incompatibility wherein features may overlap. She contends that it is less

about infrastructural boundaries than it is about patching the seams of heterogeneous systems together to complete tasks, albeit ephemeral, alternate infrastructural *alignment* and *misalignment*. Working in this infrastructural complexity, users aggregate tools, forming layers of systems with devices and system ecologies and engage in *seamless* or *seamful* information practices.

Vertesi witnessed local, dynamic engagement with digital actants and among actors to achieve task completion. Success meant using two distinct systems to complete a task; for example, a scientist aligning systems of voice communications and e-messaging, the first, to relay critical data, the second, to expound on mission potentialities. Conflict among device ecologies created "multi-infrastructural torque," (Latour 1990; Shapin and Schaffer, 1985) as in a scenario involving scientist trying to align Mac and PC platforms and media formats in order to present data.

As Vertesi's research followed knowledge workers' technology use the confines of an organizations, illuminating scenarios of *seamful* and *seamless* practices, it follows that it can be applied to the mobile knowledge worker community. Thus, there is an imperative to examine their digital-information practices with digital technologies in order to identify common barriers and technological seams that aid or hamper work. Such examination will uncover the scope of *seamful* and *seamless* in these workers' digital practices that has not yet been addressed in the literature. Applying her framework to mobile knowledge workers should uncover yet unidentified strategies they employ to interact with the technological infrastructures and how they align infrastructures and avoid breakdowns among disparate systems.

Methods

Research Design

This exploratory study of mobile knowledge workers was advanced to understand the information practices, mobile behaviors, and digital technology use. Twelve mobile knowledge workers comprise the participant sampling. Data was collected through comprehensive, semi-structured interviews. A significant theme that emerged in data analysis is mobile knowledge workers' interactions with technology. This paper aims to show the relationships between mobile knowledge workers' information practices in lieu of the associated technological infrastructures.

Data Collection

Before selecting participants, an interview protocol was created that concentrated on probing the nature of participants' professional domain; organizational role and responsibilities; work arrangement, mobility threshold, and environment; the configuration of their professional networks, professional tools and resources, with emphasis on digital infrastructure, and entailing personal or organizational acquirement, mobilization capacity; and their perceptions of resource availability, organizational challenges, and work-life balances affordances.

Initial participants were identified through purposive sampling; successive participants were found through purposive snowballing techniques. Any attempt of data saturation is implausible. Given the scope of the exploration, a limited sample was considered sufficient to investigate common elements of this demographic. Thus, the study population was also felt considered reliable.

Participants span a domain of fields, including education, IT, journalism, web and software development and consulting. Some were self-employed and other were employed by an organization. Relevant demographic details are listed in Table 1 below. Interviews ranged from 50 to 100 minutes. Information gleaned from early sampling identified notable issues and further research to explore. All interviews were audio recorded.

Table 1: Study Participants Demographics

	Gender	Industry	Role	Employment	Work setting(s)
P1	F	Education	PhD student, instructor	Organization	Co-working spaces
P2	F	Web development	Web developer	Self-employed	Home office
P3	F	Business consulting	Strategy consultant	Organization	Multiple offices
P4	M	Health IT	Knowledge management	Organization	Home office
P5	M	Web development	Web developer	Self-employed	Co-working spaces
P6	M	IT Journalism	Columnist	Organization	Home office
P7	F	Business Consulting	Productivity Consultant	Self-employed	Multiple locations, clients' sites
P8	M	IT Consulting	Consultant, Support, President	Organization	On-the-move, clients' sites
P9	M	Business consulting	Corporate trainer, speaker	Self-employed	Multiple locations
P10	M	Legal services	Lawyer	Organization	Multiple locations
P11	M	Business IT	Developer, consultant	Organization	Multiple locations, clients' sites
P12	M	Business IT	Consultant	Organization	Multiple locations, clients' sites

Data Analysis

Data collection and analysis followed initial interviews of a minority of the participants. I first listened to the first ten transcripts before starting active analysis. I then selected instances that involved digital practices, barriers and adaptation. Given the emergence of particular themes over others, notably affordances and conflicts associated with digital-technology use, subsequent interviews aimed to develop these themes further, however, without losing focus of the preliminary intent of the project. Audio recordings were transcribed verbatim and loaded into the analytical software application NVivo 10.

Primary data analysis was inductive and guided by digital barriers in technological infrastructures. Qualitative research methodologies included open coding, initial memoing, focused coding, and integrative memoing. Initial themes were found through open coding following inductive analysis and further research of IS and Human Computer Interaction (HCI) literature.

Findings

After analysis, barriers were identified and categorized into groups: 1) communications and collaboration, which includes knowledge sharing; 2) information and data management, involving data transfer, preservation, and security; 3) organizational boundaries, entailing organization restrictions; 4) and spatial considerations. While there is an admitted overlap between these sections, each experience or statement made by a participant was categorized to the dominant attribute.

Communication and Collaboration

Through the course of the interviews, the necessity of good communication tools, was apparent. Many needs were time-sensitive, others for clarity. All participants indicated that many or all of their associates were remote, that keeping up with them was priority. Others who were remote from their organization or collaborated with a network of clients, associated communication technologies as a central locus, one of virtual spaces, where information was transmitted and knowledge disseminated. Technologies included phone, email, instant messaging, text messaging, video conference, and chatrooms.

Infrastructural limitations

Barriers involving infrastructural platforms ranged from devices and applications. These were proscribed by user limits, perceived or actual; device limitations in features or capability, application feature depravation, or a combination of the last two. For instance, most users preferred laptops over tablets for robust or interactive information work, while a few were explicit about it: "I can't write on the phone. I—you know—I'm too old" (P6). When asked whether Dropbox was on her phone, she explicitly reasoned why she disliked it:

> The mobile apps of Dropbox are a little weird actually. So my phone is going crazy. So I'm not sure if I installed Dropbox on my phone yet. Hmm … Totally not working. I have to fix that. But yes, I can, I certainly on my iPad. But the way it works on the iPad is you actually have to go and grab the files. It doesn't automatically sync everything, you have to tell it what you want to sync. So if I'm traveling for example, I have to sort of go in and say okay, sync this folder before I go so I can work on it. But I don't use the iPad for that much work either, the same kind a reason; I don't like typing on glass (P6).

One participant complained about the audio quality on her laptop: “But then I got an external microphone because the one with my laptop was so crappy that it doesn’t work” (P1). Another distinguished certain things he could do on his smart phone and thing he could not:

> It’s very limited what you can do. Remote access works, no problem. Anything that re—Skype for example, would not work, because streaming surfaces on the, that type of Wi-Fi connection is terrible. It doesn’t work well. I checked FaceTime, doesn’t work. Doesn’t work at all. So, iMessage works well, and literally if you do remote access, that’s about it. So yeah, and you cannot be doing anything else. You cannot be multitasking in any aspect (P8).

Platform multiplicity.

All of our subjects indicated that they use multiple technologies for communication and collaboration. They include email, phone, instant messaging services, social media, and text messaging. Working with associates remotely, many participant emphasized the importance of open communication channels and managing multiple documents.

> Obviously from a lawyer perspective it’s very document driven. So, that’s where being able to manage documents and be able to access documents on the move is very important. Obviously we’ve got, you know, communications coming in from the clients, so whether that’s coming in via email, phone, video conference, whatever that is, that comes in, in a lot different ways (P10).

For one participant, integrating social technologies into his communication with clients and vendors had become common, and monitoring them for correspondence necessary. His experience had shown the emergence of social media as a platform for professional engagement, even with Facebook:

> It came on board in 2004 with Facebook when I was in college, and it was for social—and key word social. But now you know, people are really utilizing it. LinkedIn is another big one that people message directly

> through. And I never thought it would be a channel. Now LinkedIn has been a very big channel for vendors to me. Vendors use LinkedIn all the time. For clients they've used Facebook to message us. They've even used Twitter (P8).

He continues with his view of the decline of email as a platform:

> Because I think now email is kind of reaching that evolutionary stage where it's almost as inconvenient as paper mail. Because everybody's on Facebook, everybody's on some form of social media. I mean you can look at the statistics. People are checking those type of avenues multiple times a day (P8).

A doctoral student and lecturer said she has a lot of email traffic with students taking her class.

> For my students I always communicate through the course management software, because that way if I send it as an announcement then even if it gets lost in the email. It's recorded on the announcements page. So even if they're like, "Oh, I didn't see the e-mail," but if you came to the course page you would have seen that the announcement is there with the information (P1).

Information and communication services multiplicity

Checking for those updates, whether on-site or through email notifications, was not just necessary for the majority. A participant who works with multiple clients and through multiple mediums bundles those email into one account:

> I have a lot of emails. I have the email here, I have email for each of my clients, I have my own corporate email, a Ravel Communications, I've got Gmail. They all go to my Outlook. And then Outlook is all structured so that they've got their own folders. So I've got a Gmail folder within Outlook, and then it's broken down. I've got an A. Ravel Communications folder, I've got a Business Radio X folder, I've got a CED folder, I have a Smashing Boxes folder, and all of those come into their own, and then they've got, Outlook has such great rules you know, I just say every time something comes in from [name] put it in this folder, and it does. I'll look at it here; if it's critical I'll respond to it. But only if it's absolutely time sensitive and can't wait another two hours anyway (P3).

This informant bundle voice communication, where his Google Works calls are forwarded to his phone or Skype

> I have a Google Works account. I really only use it for voicemail and for recording. It's silly, but, when you call my Google voice number, it redirects you to my cellphone and my Skype. And if someone calls me, I can record the conversation by pressing 4, before they talk. I have recorded many conversations. I have yet to listen to a single recording, so I stopped. But it was backup. Really I that's the main reason I use Google Voice, that it chases me and it records. And I mostly picked it because I could record while talking on the cellphone in case I didn't have a keyboard in front me. But that very rarely happens.

Client-driven.

Most informants emphasized the importance of maintaining open communication channels with clients on their preferred platforms (P2, P3, P4, P5, P7, P8, P9, P10, P11). One imparted perceived difference between his ICT suite and those of his clients:

> So they have one organization they need to focus on right, potentially a third party provider. They sit in a tall building in Charlotte, there's really no need for them necessarily to have five or six different tools to do a job. Whereas for me I need to be able to communicate with various different clients with various different capabilities and the need is different. In an organization they can address their specific needs and find a tool for them whereas us we, some tools are really awesome when it comes to sharing screens, some are much better when it comes to recording an interview and they all have their benefits, and again talking about knowledge sharing. GoToMeeting, they have a phone app, so if you know you have people on the road who might need to literally drive into the side of the road and join a meeting on the phone like a GoToMeeting with a shared screen and you know that's going to happen and let's do a go to meeting (P11).
>
> Another commented on the changing role of text messaging with clients, saying that some even preferred it over email and social media channels (P8).

Because clients do not have the same technology use, proficiency, or tendencies, interacting with them caused more diversity for the majority of participants.

Colleague-driven.

Dynamic use of multiple communication devices also extends with colleagues. Most participants (e.g., P1, P4, P6, P8, P11) stressed the importance of collaboration with

colleagues to complete projects or immediate tasks. For the latter, instant messaging was stressed (P4, P6, P11, P12). A consultant counterpointed the communication practice difference between himself and his clients:

> If that's not the case and it's just me and my developer from Georgia I just want to quickly look at something, let's do Lync; don't have to schedule anything, it's right there in the chat and we don't impair anyone else. It's a choice, I guess it's just what you're comfortable with (P11).

In his organizational practice among colleagues, communication is chosen based on the efficiency of the task. Collaboration can bounce from email, to instant message, to phone: whatever is practical.

One noted that even though his company has its own email domain, he and many of his colleagues use Gmail accounts extensively for company communication (P6). The downside to this flexibility is that those Gmail and the company one are regularly used interchangeably. They also use chat in that back-and-forth process:

> And then he will read it, and if he has questions, he will shoot me questions via chat usually, or sometimes email, and then I will answer them, we'll get it in shape, it goes to a copy editor, copy editor makes sure I didn't misspell Marissa Meyer's name or anything, and, then she says it's ready, and then an editorial assistant posts it to the site. (P6).

He also related that they can be concurrently working on the draft together, while communicating through instant messaging. The breakdown occurs because he doesn't know what email service his editor will use: "He actually did the other night. But it wasn't anything urgent. I think he knows better than to send me anything urgent on the [company email]" (P6).

Knowledge management barriers

Knowledge sharing is part and parcel in remote communication. Informants intimated that document sharing happens outside of the bounds of just one tool and just

one device (e.g., P2, P10, P12). One participant admitted a technological generation gap between her and her colleagues. For collaborative projects with colleagues, email is the preferred method of sharing drafts of papers, so that there are multiple drafts of the paper floating around. She persuaded the group to share over the cloud, as she regularly has done with student peers. She shared her tactic for document naming with metadata, which was, however, not followed.

> There's the ideal version and then there's what actually happens that I am a compulsive saver so like every draft of my dissertation that I open up on a given day I will save as dissertation draft 22614 and then if I open it tomorrow it's 22714 so I go over and over and over and then I have a folder that just says past drafts and then just shovel it all in there. So I've been trying to get [a colleague] and the other grant folks to get in the habit of saying you know, we would have like our last project the acronym was CHRIL, Center for Health Reform and Independent Living, and so we would say like CHRIL Grant Proposal 22614, and then so that would be the document and then if [my colleague] was like okay let's go through and proofread that I would go through track changes, make my edits with the track changes saved and then save it as CHRIL Grant Proposal 22614 Liz edits and then he would go through and either accept them or reject them and save it back as sort of the master document.

Breakdowns occur when users don't follow the same naming conventions.

Information and Data Management

These barriers can cause issues with data preservation and dispersion of data across multiple platforms. Breakdowns occur in the latter for information retrieval (P1, P10).

Data preservation through VPN

Saving and preserving documents on a server or machine while using VPN has potential problems with connections. Internet and server connections can cause disruptions as well as another user logging in. For participant 12, this mistake manifested itself when he ended another user's session.

> There are a number of clients, some that have usernames and passwords for your individual users and then there's others that have one user and you can, you know, any of us can login to do things. Actually this came up in the first couple weeks of me working because I kicked somebody off or I got kicked off myself cause if I'm on the clients machine and then someone else logs in with that I get, I don't get to keep my session and they don't, and it doesn't say oh this user started it just kicks me off completely (P12).

Platform multiplicity

Barriers with integrating data into systems or distributing data were common. Issues with cloud service multiplicity and preference (e.g. P10, P11, P12) and calendaring integration (e.g., P3, P6, P10) occurred.

> There are issues with having multiple devices and having all the right data in the right place. So in terms of calendaring specifically, you know, anything that's… so, CED's, CED, this client that I'm here for, this calendar's real important. A lot a people here I have to communicate with based on calendaring, and meetings. Because when I'm here we meet, right, that's what we do more than anything else, because that's why you have face time, right. So, they're on Exchange. They're on Microsoft Exchange. Their Exchange system works better for communicating with Android devices than just Outlook, or even Outlook in the cloud now. So I would like Outlook in the cloud to be as good as Outlook Exchange (P10).

Another use had issues with integration and privacy, and control:

> I actually have problems with calendaring right now, because I'm having trouble with making all the technologies work. You know using an Android phone and an Android device, the… there's not a lot—Google wants to take over. It wants Google Calendar to be your calendar. Google Calendar doesn't work well for me. It's just kinda like why don't you use a Mac? The same, it doesn't, I, it's like I have to change my whole way that I think in order to make Google Calendar work for me. And it's just too open. I like the fact that Microsoft is close; I like that. It's not as closed as Apple. Apple's too closed. You know what I mean? (P3).

Organizational Boundaries

Participants who were a part of an organization or closely aligned with one indicated significant boundaries. These involved security measures involving server and software restrictions.

Server restrictions

Getting access to the company's servers, and hence vital work information, can be problematic. For participant 4, when traveling, even though he can find Internet access, if not an authorized network, he cannot access the company's servers. Therefore the accessibility of work resources is compromised.

> Getting on internet is really difficult, because if you're not on a password protected internet, you can't get on the [company] network. But we do have a way to access our email outside of the [company] network. So I can actually work with anything that comes through my email. I'll have stuff that's saved on my desktop, but I can't access my share drive, or anything like that.

Consequently, he emails himself documents ahead of time, so that he can work with them on the trip.

Participant 11 related the same problem in working with some clients. Clients may restrict access to their network by authorizing only specific IP addresses.

> So you have situations where companies have set up constraints that I couldn't connect to their site right here, right now if I wanted to. There are places that have some higher level of security clearances where down to a point where they need to know what IP your request is coming from. I can't really elaborate too much on the details but the point is there are companies where you know you shouldn't log on to your phone for instance, because phones are notoriously insecure. Public WiFi is notoriously insecure so some information was encrypted when you pass it through and some information isn't encrypted and that's where they would ask kindly that we don't do work on their side when you sit at a stoplight (P11).

His spatial freedom is circumscribed by this restriction. He indicated that in consequence he would prefer not to work outside of the office or his home office.

Data transfer

Since data security is important to many organizations, they may enforce technological restrictions that prevent data download from company devices and servers. Such is the case for participant 4. When faced with the challenge of transferring unclassified work media to his personal computer, on which he had software to modify the media, he had to leverage numerous strategies and technologies.

> I need to get this movie file between my work and my personal computer, and I was trying to figure out ways to do it. I was like, I wish I had Dropbox. I just can't—because, our inbox, in addition to being our primary mode of communication, is very, very restricted in the size limitation, so we're constantly in email jail. So I constantly have to move things to my ShareDrive, in order to make room on my email.
>
> And he's sending me like video clips that, you know, to download, and I can't download them on my work computer, so I have to do it on my, I—somehow get it on my home computer, so that I can manipulate it with personal movie software. Then I have to put it on a disk, because they don't allow flash drives on our work computers. Like you cannot use them at all. You can't use them at all. So I have to put it on a disk because for some reason they have no way of blocking [that] (P4).

Lack of support

The previous instance illustrates the lack of organizational support, if only implicit, in which that knowledge worker felt forced to circumnavigate the regulations to complete project work. Another participant complained that his organization would not support migrating company email to with his Gmail account, his primary. He felt impelled to do it himself (P6).

Spatial considerations

Among the participants, it was clear that they are presented with challenges when on both long and short trips. These can be device related, Internet and network access, and security issues, as discussed in the previous section..

Device Privation

Battery life can be an issue for longer trips, on long flights or in cars where AC outlets are not available. Aforementioned organizational security measures can also prevent access to servers and use of information and technologies. As participant 4 explained, he takes both his personal and work laptop on trips:

> I actually take both. I've been taking my personal laptop and my work laptop, because typically when I'm traveling for work, I'm constantly having to go to the east coast, which is a long flight, so for just for battery life sake, I'll bring both.

All participants but one indicated that their laptop was crucial for mobility; the minority found his tablet sufficient in some cases.

VPN access

Smart phones can be used to broadcast networks to which other devices can join. Participant 9 uses two devices concurrently, one to get the network and the other to do work: "So I can turn the iPhone on if I'm in area that doesn't have Wi-Fi, I can turn the iPhone on to be a hot spot, then I have it for the laptop or the tablet" (P9).

Participant 11 said that he had done this from a client's site as well as in the car (as a passenger) on long-distance road travel.

> Well we have access to our phones which we can VPN and create internet from, but again no, it's a matter of coordinating the skills and there are things that you can do offline. Like if I need to write an e-mail there's no

> problem in writing it in Word and then once I get to my destination copy and paste it into an e-mail.

Network Privation

These mobile workers sometimes were in states without Internet or network access (e.g. P4, P9, P11). In the previous section, there was a stated need of employing the technologies at hand to get work done (P11) but this is not always possible: “Right, but not in the airplane. So in the airplane, some of them do now. Like on Southwest you can get Wi-Fi and all that stuff” (P5).

Discussion

Participants in this study employed various strategies to overcome the barriers existing among systems, whether built into the infrastructural or institutionalized by their organization; the multiplicity of systems and services; and spatial barriers among associates and organizational digital infrastructures and support. Analysis of these barriers expose three primary adoptive strategies. Communication, collaboration, and organization barriers are addressed through the adoption of particular technology assemblages: orchestrated infrastructural constellations of technologies that address contextual, temporal, and spatial dimensional issues (Rossito et al., 2014). Information and data management barriers are remedied by data and service integration: migrating data from one or more sources into a central repository, or vice versa. Spatial barriers are ameliorated by familiarizing oneself with local infrastructure and services and leveraging them as situations arise.

Infrastructural Assemblages

While not all participants had free reign to choose their technology, made salient by organizational, particularly security, concerns, most were able to construct what Carroll (2008) describes as portfolios of technology: a sense of collecting digital resource for integration rather than just mere accumulation, which addresses dimensions of mobility and knowledge work. Those that did not were actants in the classic "push" models as described by Hagel and Brown (2006) in which organizations push tools on to workers in a top-down, tightly controlled practice (Huotari & Wilson, 2001). It is understandable that this model is unpopular among knowledge workers, given their definition as experts in their field (Drucker, 1999) and independent agents unconstrained by traditional work roles as well as physical and digital infrastructure. As Emirbayer and Mische (1998) impart, they garner past experiences, taken with situational relevancy of the present, to choose technology that facilitates what *seamless* integration of technological infrastructure. This phenomenon of smart portfolio development invariably emerged in all self-employed participants as well as three participants with organizational membership (P1, P6, P8).

Pairing

A theme that emerged during the interviews was the instance of combining platforms for communicatory or collaborative tasks. These could be ad hoc or habitual integrations. Pairing entails combining media for communicating. Leonardi, Needley, and Greber (2011) explored sequential media pairings of communication devices among managers, who they describe as adepts of ICTs. They determined that managers choose

ICTs respective of the richness entailed in the task and practice simultaneous media paring, using multiple devices conjunctively in simultaneous and antecedent multi-communicating. They resolved that these practices are ideal for knowledge sharing, resolving conflicts, and persuading colleagues, but can result in attention fragmentation and heightened stress.

Concurrent pairing

Participant strategies included using two laptops to circumnavigate organizational security measures (P4), collaborating through chatroom while writing on word processor and researching on the Internet (P6), and using his email service to record notes while on a phone call (P5):

> Usually I open up a new mail and, and I just type there, because it's automatically saved as a draft and everything, and then, you know, at the end of the call, if there's anything important I'll send it to myself, or if not I'll just delete it.

Many participants indicated using several storage services or platforms for the same data: internal and external hard drives, cloud storage, and other software like OneNote and EverNote. (e.g. P6, P7, P11) One participant leveraged cloud storage to transfer among devices, mechanizing a seamless transfer through iCloud between her iPhone and iPad Mini (P7).

For support with remote clients, this participant leveraged the immediacy and clarity of phone conversations and then remotely accessed user machines during the call:

> Right. So I'm on the phone with the client, and then what I'll do is, I'll give an explanation of the issue. I can dial right into their computer, whether it's from my cell phone, or any device. And then I get to see exactly what they're doing, and they can create—recreate that scenario (P8).

Following this strategy, of aligning two disparate systems, this support technician was

able to creating a seamless experience for the client.

Sequential pairing

This strategy can involve planning ahead and responding to developing situations. In communication practices Watson-Manheim and Belanger (2007) found that sequential media pairings aided managers in resolving conflicts and sharing knowledge. This is manifest with several participants' revelations. One informant said she uses email for most communication while phone calls are reserved for things needing clarification (P2). Two participants talked about dialogue bouncing from email, to instant message, to phone, given the circumstances and practically of the situation, both contextually and spatially (P6, P11, P12).

Another adaption using sequential pairing was to deal with this informant's barrier with network security restrictions. When he traveled he could not login to the network unless at designated work sites, so he consequently emails himself documents ahead of time, so that he can work with them on the trip (P4). Another participant, while offline, has a practice of writing emails and blogs in a word processor, and then copying them to respective platforms once online.

Technology switchbacks

Some of the participants said they switch between two different technologies for the same task, depending on the richness. Even with technologies that share the same function, note-taking, it is not uncommon to have disparate features and complexity. One participant used OneNote for robust notes and an iPhone app for short or ephemeral note (P7).

Specialized ICTs

These are technologies that users employed for efficiency, mobility, and ease-of-use, or collaborative features. Organizational software allowed one user to make lists of things-to-do, tag tasks, and show completions (P1, P10). Social media apps on her phone help one participant stay in connection with associates while on the go, and removed email out of the loop of checking social-media notifications and inter-service communication (P3).

Integrative ICTs

Technologies that integrated features, data, and services aided participants' efficiency, efficacy, and diffused information overload in minimizing the number of applications and processes with which they would otherwise interact. The key here was seamless integration of features. Google Drive was a popular medium for collaborating in composing documents, sharing documents and files. (e.g. P1, P10, P12). Project management web-software package BaseCamp integrated communication, file storage, and task management into one environment, keeping clients abreast of development lifecycle with information and email alerts (P11, P12). Using Siri on the iPhone incorporated voice technologies to read email, allowing the participant to digest email while driving (P8). Among instant messaging services, technologies such as GoToMeeting or ShareStream were advantageous for screen-sharing and taking control, instrumental for working on others' computers remotely (e.g., P8, P11, P12). An infrastructure that was pushed in a top-down was a popular mode of collaborative idea-generation and brainstorming among a group of journalists in the same organization (P6).

In the process of communicating the practice seamless, they are able to dynamically drive multiple infrastructures to share data and screens as well as transmit and preserve knowledge.

Mobile-capable ICTs

Mobile friend technologies enable spatial, and consequently, temporal, freedoms. By granting users the ability to access information and tools while on the go, their flexibility to meet with clients, short- and long-distance travel, and to work from anywhere immediately convenient is heightened. Using specialized phone apps like WorkFlowy (P1), BaseCamp (P11, P12), social media services (P3, P4) and voice-enabled, Natural Language Processing (NLP) services like Siri (P7, P8) are examples for leveraging portable ICT devices to stay up to date and manage information.

Interoperable ICTs

Using cross-platform technologies were important for participants using multiple devices, like tablets, and for sharing ICT platforms among team members and client, enabling personal and group flexibility and extended mobility. Basecamp and Google Drive are prime examples previously mentioned. Because these ICT platform are web-based, they enable shared experiences for collaborators whether using Mac or PC devices. While device screen sizes result in different viewing experience, since these platforms use responsive design techniques, there is no actual loss of information conveyance. This strategy generates seamless experience for users, despite the heterogeneity of platforms.

Integration of data and services

These are strategies which participants enacted to embrace one or more platforms for richer, extended features, for convenience, and data assurance. By bring together seamful technologies, they create seamless experiences in one platform.

Centralizing

A participant has a centralizing strategy for voice communication, where his Google Works calls are forwarded to his phone or Skype. He leverages these technologies for their greatest use of their features, recording for Google Works calls and the convenience of using the mediums of phone or Skype. Although he admits he quit the practice after determining he didn't need recordings, this tactic instilled confidence that he had a saved recording, thus enabling his mobility and spatial flexibility. Although he admits he quit the practice after determining he didn't need recordings, this tactic instilled confidence that he had a saved recording, thus enabling his mobility and spatial flexibility (P6).

One participant explained her method to aggregate and organize all her email. Because she works with multiple clients and through multiple mediums, her strategy was to centralize all her emails by importing them into one Outlook account, creating folders for each email (P3). Another manages all incoming documents from clients into one cloud storage systems called Box; he states that preserving them in one manageable locations aids in information retrieval (P10).

Distributing

This involves transferring data among systems that are not interoperable, so require manipulation in order to achieve. This could be in-place by a system or not. One participant distributed communications with students through the course management software, for in so doing she has an official record of communication besides email (P1). Although students could find announcements in a centralized repository, since they were also emailed, it is a distribution tactic.

Two participants said they migrated data among systems, to make it accessible across devices and software platforms. (P10, P11). One explained his organization's practice migrating data across applications and platforms:

> But they integrate with each other. So what we'll do is if we have a deadline in the case, it gets entered into Clio, which then gets pushed to the Google Calendar that we have, then, then gets pushed to mobile devices, or computers. So of people want it locally. So, for that gaze into Clio and it shows up on my calendar on my iPhone or iPad. You know, so all nicely integrated. So that's why we chose these systems. So you can be able to access information wherever. And you know, people have multiple calendars, so I've got you know my law firm calendar, my Curio calendar, I've got a family calendar, and those are Google oriented, so they all tie together nicely, so I can access those from any device (P10).

Local assets awareness

Taking advantage of local assets while mobile is a key strategy to overcome spatial barriers. All of the participants said that they need Internet or network access to get their daily work done. Strategies including using airport and coffee-shop WiFi, VPN hotspots using cellular networks (P9, P11), or client's infrastructures (P8, P11). Informants emphasized the important of understanding local infrastructures capabilities and potential security risks as important (e.g. P4, P11).

To overcome spatial barriers where WiFi was unavailable, two participants created hot spots with their phones to VPN on laptops, even in highly mobile states (P9, P11). One organization where employees VPN into multiple clients' computers had a problem with users getting kicked out when another use logged in with the company account. They decided to leverage Lync to broadcast when and what machine employees are on (P12). Another adaption was using Siri to leave voicemail messages to, as reminders, appointment time, etc. (P7).

Conclusion

In this exploratory examination of a small representative group of mobile knowledge workers, digital barriers among participants' infrastructural systems emerged. By importing the language of seams (Vertesi, 2014) into this analytical framework, manifested the existence of conflicts among device ecologies that cause single- or multi-instance multi-infrastructural torque and gaps in technologies that cause recurrent breakdowns and which warrant solutions. This trend of dichotomies underscored the necessity of adoptive solutions.

Participants were seen overlaying or stitching together infrastructural seams, pairing technologies to perform various tasks, ad hoc and habitually; integrating technologies and data into constellations (Rossitto, 2014) of platforms and services; and taking advantage resources at their fingertip. Both success and failures were seen. Failures prompted an urgency to enact changes. With these adoptive strategies, they improve their mobile situation, enhance their capacity to engage with multiple actors

across time and space, and guard from information overload, by discriminating among the number of platforms to use.

This analysis identifies barriers and strategies to overcome them. While some barriers may remain persistent, such as organizational barriers, this study hopes to aid the studied community, along with their organizations. Given the rising population of mobile knowledge work, and the emergence of new technologies, it is hoped that future studies will delve into these issues more deeply through shadowing techniques, diaries, and broadening the representative population.

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