

Home Computing Unplugged: Why, Where and When People Use Different Connected Devices at Home

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ABSTRACT

We investigate how technology usage in homes has changed with the increasing prevalence of mobile devices including Tablets and Smart Phones. We logged Internet usage from 86 Belgium households to determine their six most common Internet Activities. Next, we surveyed households about what devices they own, how they share those devices, and which device they use for different Internet activities. We then conducted semi-structured interviews with 18 of 55 households that responded to the survey in which participants explained their device usage patterns and where they use technology in their home. Our findings suggest that the nature of online activity and social context influence device preference. Many participants reported that their Desktop PC is now a special purpose device, which they use only for specific activities such as working from home or online gaming. Compared to past studies, we observed technology use in many more locations in the home, most notably kitchens and bathrooms.

Author Keywords

Domestic Technology; Empirical Study; Residential Network

ACM Classification Keywords

H.5.m [Information Interfaces & Presentation (e.g., HCI)]: Miscellaneous.

INTRODUCTION

What happens to technology use in homes as they become saturated with devices? Is contention for devices, frequently observed in past studies of home technology, still an issue because everyone wants to use the latest and most capable device? Or do households reach a point where there are enough devices to go around? Do people still share devices? How has the introduction of Tablet computers into homes changed the usage, sharing, and location of computing at home? Our investigation continues the tradition of past studies examining home technology use in countries with well-developed Internet infrastructure and in households at the leading edge or middle of the adoption curve (e.g. [1, 3, 5, 18, 21]). Studying these households helps researchers understand both current usage and developing usage trends.

We had the unique opportunity to collect logging data of Internet usage from 86 household in Kortrijk, Belgium, survey the households, and then interview 18 households in detail about their usage. We sought to understand what devices our participants use for different computing activities, where in the house they use technology, and how usage changes during the day. Our research questions were:

1. How are frequent computing activities (e.g. email, gaming, etc.) spread across devices? Prior logging and survey studies (e.g. [1, 18, 20]) typically examine computing activities on a single computer in the home. We broaden this focus to understand from participants which devices they choose for different computing activities and why.
2. Where in the home do participants use technology and does this change based on activity? Relatively recent studies found technology used in homes in only a few locations. For example, in 2006 Woodruff et al. observed Laptops were used in a few favoured places [21].
3. How does device usage and computing activities change during the day? Karlson et al.'s study of information workers found temporal patterns of multi-device use across mobile phones and computers [9]. Focusing on home use, we wanted to understand the temporal dynamics of people's computing activities and device usage.

While the general adoption and increased usage of mobile devices has been widely reported, our study findings provide deeper insights on why participants are choosing these devices and contained some interesting surprises. For many of our participants, computers, particularly Desktop PCs, have become niche devices used only for very specific activities such as working from home or to play particular online games. Tablets and Smart Phones have replaced established computing platforms, e.g., Laptops and Desktop PCs to become the default "generic" computing devices used for a wide range of activities.

Perhaps the most dramatic change from past studies (e.g. [3]) are the places that our participants use technology in their homes. Specifically kitchens, targeted in the past by failed commercial systems like 3Com's Audrey and research prototypes (e.g. CounterActive [8]), and bathrooms are now common locations for several computing activities. Another change from past studies is that our participants did not report contention for devices. Taken together these and the rest of our findings demonstrate the many ways in which technology saturation has changed computing usage in homes.

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RELATED WORK

Since computing technology first entered homes, researchers have been studying its use. This includes demonstrating “the work to make the home network work” [6], investigating methods of informal technical support [16], and identifying roles households members play in managing technology [19]. Home usage of many applications from video chat [10] to game playing [17] has been studied. Survey studies highlight changes in household use of technology. Venkatesh et al.’s longitudinal analysis of four national U.S. surveys (1999, 2003, 2008, 2010) showed increases in number of activities performed on computers, the rise of social media applications, and increasing use by women [20]. A 2012 Pew Internet Survey focusing on teenage technology use in U.S. households found a substantial growth in smart phone adoption and that one in four teens mostly go online using their phones [13]. While these studies and others highlight interesting aspects of technology use in households, most relevant to our study is research on logging computing usage and exploring the impact of location on the usage and sharing of technology.

Logging Use of Technology at Home

The HomeNet Field Trial placed computers with logging installed into 48 households in Pittsburgh in 1995 [11]. As households went online for the first time, researchers observed participants discovery of communication tools and found teenagers were some of the heaviest users and sources of expertise. Beauvisage reported on a 19 month logging study of 661 French households ending in 2006, that collected data primarily from a single household computer [1]. Beauvisage classified PC users into five distinct types based on applications used: Web-oriented Users (42% of his user population), Instant Messaging (14%), Gaming (11%), Multimedia (14%) and Serious (18%). These types correspond to five of the top six Internet activities we observed in our sample (see Table 1). In 2007, Rattenbury et al. [18] logged the use of a mobile computer, either a laptop or provided ultra-mobile pc, by 169 participants across 4 U.S. cities and interviewed 21 of them. They used the metaphor of plastic to characterize the opportunistic, unplanned, non-immersive way participants used the device. In our study, the combination of qualitative interview data and logging data for all Internet connected devices allows us to log application usage more broadly and interview participants in detail to learn how they decide which devices to use for different types of Internet activities.

These studies and our own took place in countries where the Internet is not a constrained resource and our findings apply only in these contexts. Researchers working in infrastructure-poor settings have demonstrated how computing behaviour changes. For example, monthly bandwidth limits in South Africa challenged households to stay within their limits with little understanding of what applications were using bandwidth [4] and people in Kenya planned ahead offline before engaging in “deliberate interactions” online [22].

Locations and Sharing of Technology at Home

Many previous studies of home technology have emphasised the interaction between the location of the technology and its

use. This was particularly relevant for early studies of desktop computers which had fixed locations. For example, Frohlich and Kraut observed that putting computers in private spaces (e.g. bedrooms) in the home discourages sharing, while having computers in public spaces such as kitchens and family rooms encourages sharing [5]. In a study of Laptop usage in homes in 2006, Woodruff et al. found Laptops were portable rather than truly mobile. Participants generally used their devices in two to three favoured places [21]. In the Rattenbury et al. [18] study, the mobile pc was commonly used at a dedicated desk or couch, although participants also mentioned other locations including the bathroom and while driving.

Brush et al. categorised the locations of Desktop and Laptop computers, Game Consoles, TVs, Music Players and Phones in 15 homes in the northwest U.S. in 2007 [3]. They found 41% of computers were in private spaces, almost double the 24% Frohlich and Kraut found in 1996 and 2001. Brush et al. also found that computers in public spaces were typically shared while less than half the computers in private spaces were shared. Our study offers the opportunity to re-examine the location and sharing of technology in homes five years later with increased adoption of Smart Phones and the introduction of Tablets which were essentially non-existent in homes in 2007.

STUDY METHODOLOGY

Our study was conducted as part of the Living Lab Project¹ based in the city of Kortrijk in Belgium. We collected data using i) Internet activity logs ii) a survey and iii) semi structured interviews.

Internet Activity Log

The Living Lab project seeks to study users’ experience with new fiber-based digital services especially for multimedia and health care. To do this, with the assistance of the city office of Kortrijk, Living Lab recruited 86 households that consented to having network packet inspection capabilities available on the backend service routers in exchange for free fiber-optic Internet connection for two years including installation. The backend service routers monitor every single network packet and record application level information including protocol, Up/Down packet size and URL (protocol, domain name, and port number). This information is used to categorise network traffic into a fixed set of 75 networked applications and web portals (e.g., Skype, YouTube, Facebook, etc.). This application set is predefined by the router manufacturer and corresponding filters are implemented in the router firmware. Due to privacy and legal concerns, our access to the data set is limited to the application (standalone or web based) or protocol name and corresponding Up/Down traffic (hourly aggregated) for each household. We collected these data on a daily basis from June 20, 2012 to August 19, 2012 that yielded 9,288,000 hourly data points for 86 families over 60 days.

To address the main research questions of this study, i.e., understanding device, temporal and spatial dynamics of Internet activities in domestic environments, for the survey and interviews we focused on the six activities that were most

¹<http://www.leylab.be/english>

Table 1. Top 6 Internet Activities and Corresponding Applications

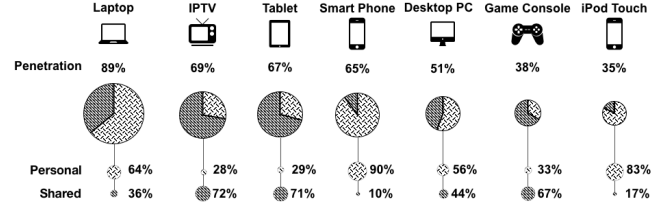
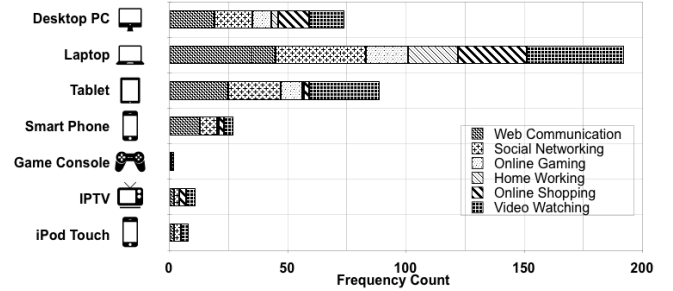
ID	Activity	Applications and Protocols
1	Web Communication	POP3, IMAP, SMTP, MS Exchange, Domino, Skype, SIP, Betamax VoIP, Google Talk, RTP, XMPP, MSN Messenger, Asterisk, RTSP, TeamSpeak, WebEx, IRC, OoVoo
2	Online Social Networking	Facebook, Twitter, Google+, MySpace, Flickr, Photobucket
3	Online Gaming	Steam, World of Warcraft, XboxLIVE
4	Home Working	Teredo, TLS, GRE, Citrix ICA, SSH, Telnet, Remote Desktop, LDAP, Citrix IMA, IP Printing
5	Online Shopping	Amazon, eBay
6	Video Watching	YouTube, HTTP Video, RTMP Streaming, Shockwave Flash, SHOUTcast, Real Player, BBC iPlayer, PPTV

popular during the monitoring period: Web Communication, Online Social Networking, Online Gaming, Home Working, Online Shopping, Video Watching. These activities and their corresponding applications and protocols are shown in Table 1. The activities were determined by first categorising the 75 logged applications (standalone, web based, and protocol specific) into 8 distinct activities following to some degree the taxonomy suggested in [12]. We then selected the most popular activities based on accumulated network traffic, frequency and temporal regularity of engagements during the monitoring period. These activities covered 50 applications as shown in Table 1. For Online Gaming and Online Shopping activities, we monitored only a limited number of web portals. However, in the study we did not restrict these activities only to these portals and accordingly in the survey and interviews asked the participants to reflect upon their overall experiences with these two activities irrespective of applications.

Survey

To gain insight on the types of Internet connected devices families own, the degree of shared ownership, and how these devices are used for the six most popular activities in the Activity Logs, we asked participating households to complete an online survey in Fall 2012 (one per household). We received responses from 55 families out of the 86 participating families. Figure 1 reports the device penetration and ownership dynamics. Laptop (89%), IPTV (69%), Tablet (67%), and Smart Phone (65%) were found to have a fairly high penetration rate, where as Desktop PC showed a rather low penetration rate of 51%. Most families clearly adopted a shared ownership approach for Tablets, Game Consoles and IPTVs, i.e., 71% of the Tablets were attributed to shared ownership. Smart Phones and Mobile Music Players (iPod Touch²) are where we observed strong individual ownership, e.g., 90% of the Smart Phones and 83% of iPod Touches were attributed to individual ownership. The survey also collected information on how these devices are used to perform the six internet activities selected for our study. Figure 2 shows that usage was spread primarily over four devices: Laptop, Tablet, Desktop

²iPod Touch was the only Internet connected Mobile Music Player that we received in the survey responses.

**Figure 1. Percentage of Device Penetration and Degree of Shared Ownership among the 55 Participant Households.****Figure 2. Survey Response on Device Usage Preference for Different Internet Activities.**

PC and Smart Phone. To gain deeper insights on usage dynamics, i.e., why a certain device is preferred over others for a specific activity and what factors influence this preference, we then interviewed several families from the 55 survey respondents in the next stage of the study.

Semi-Structured Interview

We recruited 18 families for semi-structured interviews. We selected families that engaged with at least four of the selected activities during the monitoring period and had at least four different devices in the home. To collect data from these families about how and why they use different devices for different Internet activities, two researchers interviewed each family at their home during January and February of 2013. Each interview typically lasted about 90 minutes. The home visit had four components: a demographic questionnaire, sketching exercise, semi-structured discussion and a tour around the house - following the method used in [3, 6]. The entire visit was audio taped for later analysis.

The 18 families had 62 people in total, of which 55% were female and 52% were adults (age range 18-55). Two of our families had children who were young adults (age range 19-22), five families only had teenagers (aged 13 or older), three had only adolescents (7-12 years old), four families had only toddlers (0-3 years old), and four families did not have any children (two young couples, and two senior couples whose children live elsewhere) in the home. Our families ranged from those living in private homes (15 families) to smaller apartments (3 families) and included retired seniors, single parents, and families with two working parents. We requested the families to have all members present for the interview and achieved that for 10 of the 18 families. The families all resided in the city of Kortrijk in the north west of Belgium. Each family received two bottles of wine as a gratuity for participating in the interviews.

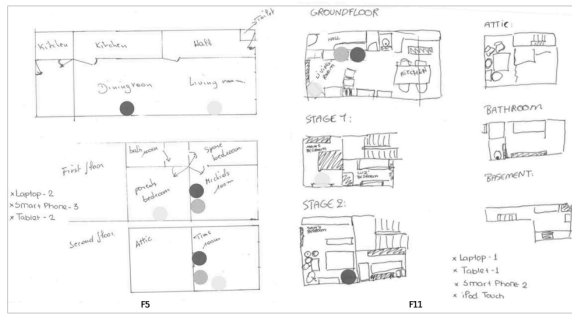


Figure 3. Example Sketches of Floor Plan by Two Families (F5 and F11) Annotated with Colored Dots for Different Devices.

We started our visit by introducing ourselves and explaining the objective of this study and its possible implications. Then we gathered demographic information, and asked one of the members of the family to sketch a floor plan of their house. Participants then used red, blue and yellow circular stickers to indicate the locations of the Desktop PCs, Game Consoles and IPTVs they used in their home. For mobile devices, e.g., Laptops, Tablets, Smart Phones, and iPod Touches, participants denoted that they used or carried these devices with them around the house. We asked the number of each of these device types they owned and noted them in the sketch. Figure 3 shows two example sketches. Then, for each device (static and portable) we collected additional details on ownership - individual or shared and who used the device. While doing this sketching exercise, we allowed family members to interact and share some facts about device locations, ownership and use, and these often led to interesting discussions, e.g., how a specific device (a Desktop PC) has changed its location over the years (from Living Room to Bed Room) or how a particular member (a young son) of the family use a specific device (his iPhone) at specific location (the bathroom), etc.

Next, we had a structured discussion where we asked participants to describe their device preferences for different activities. To ground the discussion in their actual use, we showed each family an Activity-Trajectory graph illustrating their logged activities, see example in Figure 4. For each of the six activities, we asked who were primarily engaged with this activity, which devices were preferred and why, and whether time and location influence their device selection. To stimulate discussion of possible reasons for selecting a particular type of device for an activity, we presented the participants with a list of ten possible factors.

Five factors related to *Device Context*: Screen Size, Portability, Interaction available (e.g. keyboard), Always On, and Usability. Two factors related to *Software Context*: Application related and File System. Finally, three related to the *Usage Context*: Physical Setting, Communality (Shared Use) and Multi-tasking (using device while doing other non-device related activities). As participants described their choices of devices for different activities, some additional themes emerged for certain activities such as perceived trust of the device. We categorised the emergent themes under the general factor of Usability and describe them in more detail in the relevant activity section below.

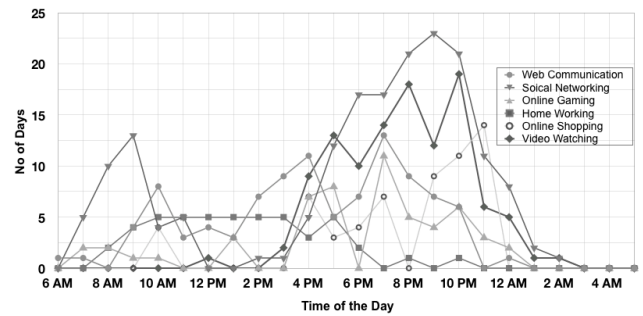


Figure 4. Daily Activity Trajectory of a Representative Family

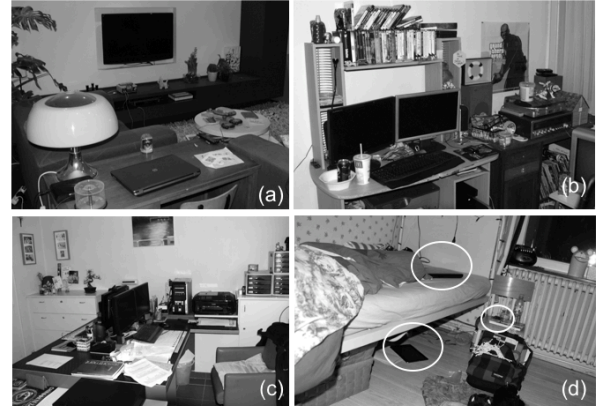


Figure 5. Example Usage Locations of Different Devices in (a) a Family Living Room, (b) a Teenage Son's Bedroom, (c) a Home Office, and (d) a Teenage Daughter's Bedroom.

We concluded our visit with a home tour, visiting each device indicated on the sketches. For mobile devices used in multiple locations, we visited all of the locations where they were used. We also took pictures of each device in its primary location within the home. Figure 5 shows four example locations. We analysed our data by counting the devices used for each activity in each household and coding its selection reasons, time and location against each activity. Observations against these codes were then analysed using affinity diagramming [2] to derive themes.

STUDY RESULTS

The interviews and sketches gave us a fascinating picture of the device, spatial and temporal dynamics with respect to the selected six activities in domestic environments. In this section we discuss the study results from three perspectives. First, we discuss which devices were preferred for a specific activity and why. Next we describe the spatial dynamics observed with respect to different activities and different devices. Finally, we discuss the temporal dynamics observed again in relation to different activities and different devices.

Understanding Activity Dynamics

We now describe device usage preferences for the top six activities we asked participants about.

Web Communication

For Web Communication, which includes both synchronous (e.g. Skype, Google Talk) and asynchronous communication

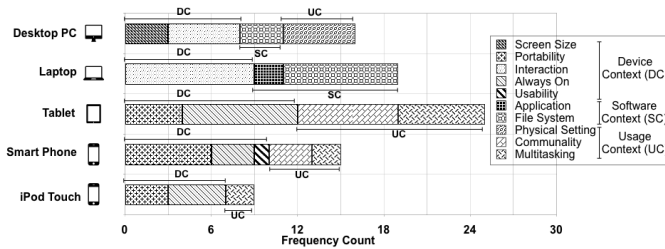


Figure 6. Frequency Distribution of Factors Influencing Device Preference for Web Communication.

(e.g. email), participants reported using five of the seven devices we asked about. As a primary device for this activity, 43% of the participants who own a personal or shared Tablet preferred using it (9 of 21 participants), 38% preferred a Laptop (11 of 29), 33% preferred an iPod Touch (3 of 9), 30% preferred a Smart Phone (8 of 27) and 18% preferred a Desktop PC (4 of 22). Not surprisingly, IPTVs and Game Consoles were not used for Web Communication. Figure 6 shows the influence factors participants reported influenced their selecting of a particular device for web communication (participants could indicate more than one factor). We conducted a two-way contingency table analysis to see if these factors affected people's choices about using a specific device for web communication, and found a significant association - Pearson $\chi^2(36, N = 84) = 130.7435$ and $p < 0.001$. Examining the reasons behind this preferences, for Tablets, the combination of *Portability* and *Communality* (shared use) was the main factor for selection. Several participants stated that they engage in video calling with their friends and families often with Tablets, because they are portable and can be passed around easily.

We found that *Interaction Modality* and *File System* were the main reasons for participants to prefer Laptop over other devices. Revisiting the interview transcripts, we observed that by *interaction modality* participants primarily referred to the keyboard or in general the haptic experience. Web communication includes e-mail clients and text-chatting applications and many of the participants mentioned that they prefer to use tangible keyboards to touch screen ones while typing. A member of F3 (Husband, Age:43) said:

"I like to use a physical keyboard while typing emails, I can type faster and feel more comfortable than using a touchscreen keyboard."

Similar responses were received from multiple other participants. Additionally *File System* was found to be an important factor as they mentioned that with Laptops they could easily attach and save files while writing emails, or chatting.

Online Social Networking

We found that the device usage was again distributed over the same five device types for the Social Networking activity (e.g., Facebook, Twitter, etc.). As a primary device, 56% of the participants who own a personal or shared iPod Touch preferred using it (5 of 9 participants), 52% preferred a Tablet (11 of 21), 44% preferred a Smart Phone (12 of 27), 21% preferred a Laptop (6 of 29) and 18% preferred a Desktop PC (4 of 22). Figure 7 shows the spread of the influencing

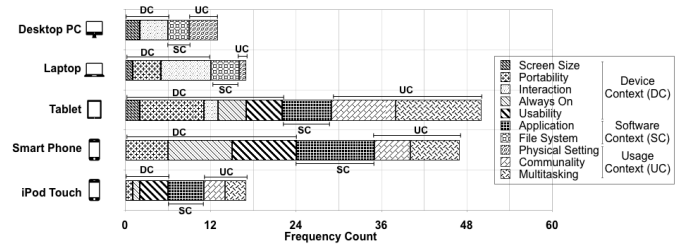


Figure 7. Frequency Distribution of Factors Influencing Device Preference for Social Networking.

factors over the device selection. We conducted a two-way contingency table analysis to test the dependency of these factors affecting people's choices about using a specific device for social networking, and found that there was a significant association - Pearson $\chi^2(36, N = 144) = 140.6821$ and $p < 0.001$. Looking further into this, we observed that the combination of *Portability*, *Multitasking* and *Communality* was the primary factor influencing the usage of both Tablet and Smart Phones. One member of F7 (Husband, Age:33) mentioned:

"I do all my social networking on my iPad in the evening with my wife while she is in the kitchen preparing dinner or watching TV in the living room. Definitely I hear less complaints for not spending time with her (smiling...)"

Other participants expressed that the form factor of Tablets and Smart Phones allow them to do multiple light weight activities like cleaning, watching TV, or preparing coffee while checking their social networks and occasionally sharing it with other family members. Communality or shared use was interesting especially for Smart Phones, as one might expect that the small screen size might not be suitable for shared activities. But our findings clearly indicated that screen size does not influence communality at least for social networking activities, as Laptop or Desktop PCs with larger screen sizes were not preferred over Smart Phones.

Another important observation was the influence of *Application* factor. To our surprise, a number of participants stated that they prefer using the Facebook application on their Tablets and Smart Phones because the user interface is clean, without advertisement, and only presents information that is useful and easy to glance through. A member of F12 (Eldest Daughter, Age:21) said:

"Facebook interface is much better on iPad and iPhone, clean and ad free. I like it that way, I can scroll through my feeds quickly."

Several other participants had similar opinions, which led to the frequency of the *Application* factor in Figure 7. Furthermore, the push notification feature available in these mobile applications, a byproduct of the devices being *Always On*, was mentioned as a factor that led to a preference for using these mobile devices. Many of our participants said that most of their social networking activities are triggered by the push notifications either on Tablets or Smart Phones.

Online Gaming

Online Gaming in our Activity Logging is unfortunately restricted to a limited number of applications, e.g., Steam,

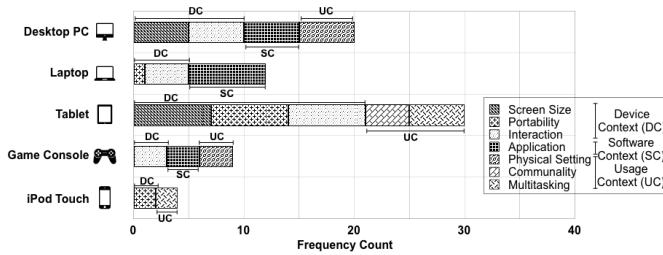


Figure 8. Frequency Distribution of Factors Influencing Device Preference for Online Gaming.

World of Warcraft, etc. However, during the interviews we asked the participants to describe their engagement with any types of computer games that required Internet connectivity. Thus, our discussion here is not limited only to the applications mentioned earlier in the Online Gaming category. As a first choice device, 46% of the participants picked a personal or shared Game Console (6 of 13), 45% picked a Desktop PC (10 of 22), 44% picked an iPod Touch (4 of 9), 41% picked a Laptop (12 of 29) and 33% picked a Tablet (7 of 21). One interesting observation, which might be counterintuitive, is the lack of use of Smart Phones for Online Gaming, especially when an iPod Touch is used by 44% of the participants who had access to one. Analysing the ownership of these iPod Touches among the families, we identified that teenagers owned 89% of the devices and they did not possess Smart Phones and Tablets of their own. So, one explanation could be that these teenagers use iPod Touches for playing online games, however adults prefer other devices with relatively larger screens e.g., a Tablet, or a Desktop PC as reflected in Figure 8.

Figure 8 shows the spread of the influencing factors across the devices. We conducted a two-way contingency table analysis to see if these factors affected people's choices of a specific device for Online Gaming, and found to have a significant association - Pearson $\chi^2(24, N = 75) = 66.3912$ and $p < 0.001$. Scrutinising these factors, Tablets were mainly preferred for the combination of *Portability*, *Multitasking* and *Communal*ity. A number of participants mentioned that the Tablet is an ideal device for them to play games with their kids and with their partners while watching TV.

Interaction Modality and *Application* were the main reasons for the participants to prefer Laptop and Desktop PC. The majority of the Online Gamers in our families were teenagers and young adults. Revisiting the interview traces, we identified that this generation primarily prefers Laptops and Desktop PCs for tangible game controllers and strategic games that are only available on these platforms. In fact, several participants from this generation expressed that they use the Desktop PCs only for playing these games, and prefer to do all other activities in other platforms, ideally mobile ones.

Home Working

Nine families in our study had members who work from home at least once a week and these participants clearly preferred a Laptop (56%, 5 of 9 Laptops owned by these families) or a Desktop PC (44%, 4 of 9) for their home working activities that include primary use of enterprise applications, e.g. Cit-

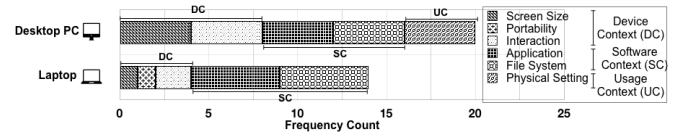


Figure 9. Frequency Distribution of Factors Influencing Device Preference for Home Working.

rix, Remote Desktop Client, etc. Figure 9 shows the spread of the influencing factors across these two devices. We conducted a two-way contingency table analysis to see if these factors affected people's choices about using a specific device and did not find any significant association - Pearson $\chi^2(5, N = 32) = 6.8432$ and $p = 0.2326$. As expected *File System*, *Application* and *Interaction Modality* were critical for both the devices. However, one interesting observation was the *Physical Setting* factor for Desktop PC. A number of participants expressed that they prefer semi-private and ideally quiet setting with flat surface for concentrating on their work related activities. In the spatial dynamics section we will discuss this notion of Home Office and the implications for peoples engagement with computing activities.

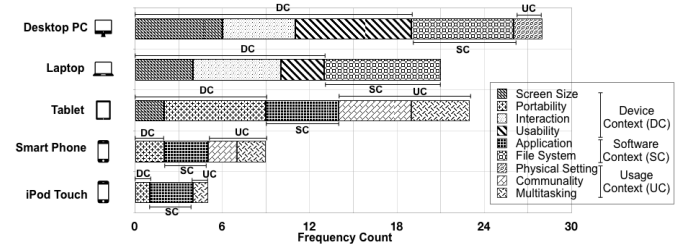


Figure 10. Frequency Distribution of Factors Influencing Device Preference for Online Shopping.

Online Shopping

The Online Shopping activity in our log was limited to only two applications - Amazon and eBay. However during the interviews, we asked the participants to express their engagement with any types of online shopping activities including grocery shopping, holiday and travel arrangements. As a primary device for this activity, 43% of the participants who own a personal or shared Tablet preferred using it (9 of 21 participants), 41% preferred a Desktop PC (9 of 22), 34% preferred a Laptop (10 of 29), 33% preferred an iPod Touch (3 of 9) and 22% preferred a Smart Phone (6 of 27).

Figure 10 shows the spread of the influencing factors across the devices. A two-way contingency table analysis showed that there is a significant association between these factors and people's choices about using a specific device for Online Shopping - Pearson $\chi^2(32, N = 86) = 94.7053$ and $p < 0.001$. Examining the reasons behind this association we found that *Interaction Modality*, *File System* and *Usability* were the main reasons for the participants to prefer Desktop PCs and Laptops. Particularly, the keyboard was crucial in this case as people need to type in addresses and payment details. Also, participants expressed that they prefer these two platforms as they can save receipts and print easily when necessary. A representative quote from a participant in F5 (Husband, Age:37) was:

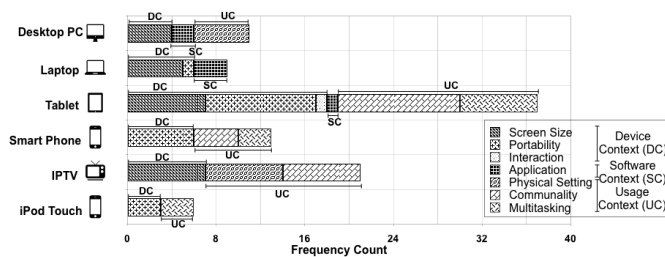


Figure 11. Frequency Distribution of Factors Influencing Device Preference for Video Watching

“I prefer my Laptop to do most of my online shopping and travel arrangements, I can organize the receipts in folders, make a print out, and so on. Also, Firefox in my Laptop remembers my passwords and other details so I do not need to type and can do things faster.”

One very interesting theme we observed was a sense of trust in particular devices which we categorised as *Usability*. Several participants expressed that they feel more comfortable and safer providing their credit card information using a Laptop or a Desktop PC. This perception was seen mostly among participants 40 and older. One member in F14 (Wife, Age:47) stated:

“I do not know why but I feel safe with my PC to do on-line shopping, I know I can use Amazon with the Tablet as Sam (her son - young adult) does, but I just do not feel comfortable, may be habit....”

It was fascinating to observe people associate trust with particular devices rather than shopping portals. We observed a contrasting preference among younger generations where mobile devices were more popular. *Communality* and *Application* were the main factors for their selection. Many of the participants expressed that the user interface of Amazon and EBay on mobile devices are cleaner, easier, and faster to browse. Furthermore, *Portability* of these mobile devices allowed them to browse their items of interests together with their partners or other family members while watching TV in the evenings or late nights (*Multitasking*).

Video Watching

Many of our families possessed DVD/ Blu-ray Players for offline video watching. However, in this section we only report their experiences with online Video Watching as during the interview we restricted our discussion to streaming videos only, i.e., watching YouTube, BBC iPlayer, etc. As a first choice device, 62% of the participants picked a personal or shared Tablet (13 of 21), 58% picked an IPTV (7 of 12), 44% picked an iPod Touch (4 of 9), 33% picked a Smart Phone (9 of 27), 31% picked a Laptop (9 of 29) and 27% picked a Desktop PC (6 of 22). Figure 11 shows the spread of the influencing factors over the device selection. We conducted a two-way contingency table analysis to see if these factors affected people's choices about using a specific device and observed a significant association - Pearson $\chi^2(30, N = 97) = 89.3371$ and $p < 0.001$. We identified that the combination of *Communality* and *Portability* was the key behind the selection of mobile devices. Several participants mentioned that they watch YouTube with their partners and kids as they can pass the device around, and bring

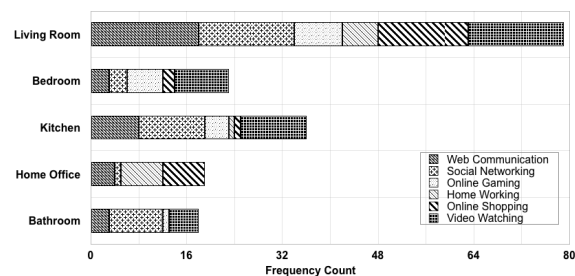


Figure 12. Distribution of Activities in Different Locations in the Home

it closer if necessary. Furthermore, a number of participants mentioned that they use Tablet and Smart Phone as second screens to decide on a movie by looking at trailers while watching regular TV programs. Once decided, they switch to IPTV to watch the movie on larger screen. *Multitasking* was another key reason for selecting Mobile Devices for several participants, as one participant from F11 (Wife, Age:31) expressed in a representative quote:

“I spent a lot of time watching recipes on YouTube, especially while cooking in the kitchen. I usually use my Tablet, I like its size, easy to handle...”

Laptop and Desktop PC were primarily preferred for the *Screen Size* and *Application*. In contrast to our previous observation on the value of mobile user interface for Social Networking and Online Shopping, several participants mentioned preferring the user experience on Laptop and Desktop computers, particularly for searching for a specific video.

Understanding Spatial Dynamics

In the previous section, we have reported the device preferences of our participants for the six activities selected for this study. In this section, we shift our focus to the spatial dynamics we observed in the homes of our families with respect to these activities and devices.

Earlier studies on understanding domestic technology split the home locations into private and public spaces for objective discussions [3, 5]. However, in the analysis of our study we coded the locations of activity and device use with labels as indicated by the participants during the interviews, e.g., Living Room, Home Office, etc. Figure 12 shows the distribution of activities that occur at different locations in the home. Living Room certainly was the most popular location for all kinds of activities, which is not unexpected, as we have discussed earlier how mobile devices were dominantly used for most of the activities. However, to our surprise, Kitchen was the second most popular location. This is a quite contrasting as compared to earlier studies where very little computer use in the Kitchen was observed [3]. We argue that the combination of communality and multitasking opportunity with Tablets and Smart Phones is the key reason for this shift.

Bedroom was moderately popular location for Online Gaming and Video Watching. Scrutinising this further, we identified that these were mostly bedrooms of teenagers and young adults with personal Laptops or Desktop PCs. We consider that for this age group, such usage pattern is expected, as they usually prefer their own private space in the home. This was

also evident by remarks from multiple participants, for example one participant from F13 (Youngest Son, Age:15) expressed:

"I like to play games and do my stuff in my bedroom, I like it quiet, and no disturbance from my sister..."

Home Working activities were mostly observed at designated workspaces, e.g., Home Office. However, some of our participants also work in the Living Room and Kitchen. Similar to what Mateas et al. [14] observed, these places were always equipped with large flat surfaces, e.g., a dining table, a work table, etc. Online Shopping and Web Communication were also popular activities in the Home Office. Several participants mentioned that the availability of printers and physical keyboards was the prime factor for choosing Home Office for these activities.

Another observation was the range of activities that occur in the Bathroom again in sharp contrast to reports of previous studies [3]. In fact, for some activities, e.g. Social Networking, Bathroom was more popular than Bedroom. As shown in Figure 12, video watching was also popular in the Bathroom. From the interview transcripts, we observed an interesting co-relation between Video Watching and Social Networking that occur in Bathrooms. One participant from F9 (Only Son, Age:16) mentioned:

"I usually do my Facebooking in the Bathroom, good use of my time (smiling..) and sometimes I watch videos there too but mostly the ones that are shared by my friends on Facebook."

Similar remarks from other participants suggest the fact that most of the video watching activities in the bathroom were triggered by social networking.

Looking at the locations based on device usage, we observed that fixed devices, e.g., Desktop PCs, Game Consoles and IPTVs were mostly used at public spaces in the home, e.g., Living Room and Kitchen. We also observed some use of these fixed devices in the Bedroom, however these locations were mostly attributed to teenagers and young adults. Desktop PCs also had a dedicated use in the Home Office. For Laptops, we noticed pervasive use throughout the home, which was slightly in contrast to the usage of Laptops in a few favored places that Woodruff et al. [21] noted. We observed true pervasive use of mobile devices everywhere in the home, including the Bathroom where the use of Tablet, Smart Phone and iPod Touch was popular. The exceeding availability and affordances of these mobile devices actually allowed them to take over the role of Laptops and Desktop PCs in the domestic environment, especially for the younger generations. For example, Brush et al. observed in [3] that Laptops were extensively used by young people, in our study we observed the same, but for mobile devices.

Understanding Temporal Dynamics

In this section, we shift our focus on to the temporal dynamics we observed during the study. In our analysis we coded the time of activity and device usage with labels as indicated by the participants during the interviews and this typically spanned across six temporal periods: morning (06:00 - 11:59), noon (12:00 - 13:59), afternoon (14:00 - 16:59), evening (17:00 - 19:59), night (20:00 - 22:59), late night (23:00 - 12:59).

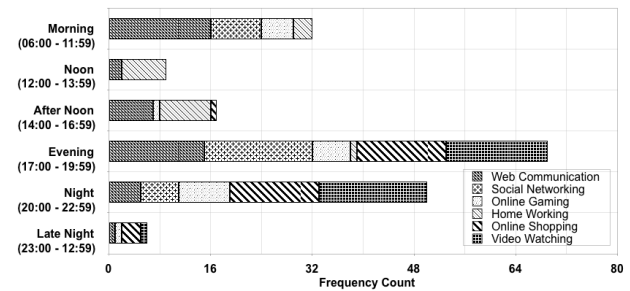


Figure 13. Distribution of Activities at Different Times of the Day

evening (17:00 - 19:59), night (20:00 - 22:59) and late night (23:00 - 12:59). Figure 13 shows the distribution of activities across times of the day.

We found that the majority of the participants spend time on Web Communication either in the morning or in the evening with very few fragmented interactions at night times. This pretty much matches with the schedules of working adults who mentioned that they prefer to check emails before and after work. A similar pattern was observed for Social Networking, which was surprising as we expected that the social networking activities would spread through out the day, especially considering the number of younger participants in our study. Analyzing our interview traces, we identified that during day times most of the teens and young adults prefer to spend time outside physically with their social circle. One participant from F2 (Second Son, Age:16) expressed:

"I used to check my Twitter in the morning to know what is happening with my friends, but it took way too much time and I was often late for school. Now I stopped and only do it in the evening...and after school I spend time with my friends anyway..."

Another young adult from F6 (Oldest Son, Age:20) mentioned:

"I prefer to hang out with my friends during the day, and leave all my facebooking for the night."

One interesting observation was the time spent in the morning for Online Gaming, and we found that a number of kids play Online Games early in the morning before going to school, which in fact was unknown at least to two parents before our interviews with them. We also observed that people spent time on Online Shopping only in the afternoon or later in the day. Online shoppers in our study were mostly the working adults or retired seniors, and they mentioned that they prefer to do browsing online shops ideally in relaxed time, which is typically in the evenings and later. For Video Watching, we noticed that the temporal spread was primarily towards the later parts of the day. In fact, none of our participants mentioned that they watch online videos during daytime. This suggests that the temporal pattern of Online Video watching is similar to television watching habits of working adults. Additionally, we also observed that evenings and nights - so called *family time* are also the period when people do most of the multitasking activities, e.g., cooking while using their Smart Phone to check Facebook, or watching TV while using their Tablets to browse Amazon etc. This was also evident from the comments of multiple participants, e.g., a member of F11 (Husband, Age:33) expressed:

"In the evening, I am in my couch...relaxing, when I pick up my iPad, play Angry Birds or browse Amazon while watching TV.."

In general, we observed that families with young children spent time on online activities on a different schedule than families with no children or with teenagers present. For example, most families with young children start their online activities after 8:00 PM (when kids are in the bed) with light or intermittent activities during afternoon and early evenings. From a device perspective, we did not observe any surprising influence of time on device usage as we found for activities and locations.

A Demographic Perspective

Our analysis in the previous sections primarily focused on uncovering contextual facts that are changing computing practices in domestic environments. In this section, we shift our focus on understanding this change through a gendered lens. Revisiting our interview scripts, we have segmented each of the analysis components into male and female groups and conducted Fisher's exact test to determine if device ownership, activity participation, and corresponding device, location and timing preferences are differed by gender. However, for all except one cases, we could not find any evidence ($p > 0.001$) of significant difference by gender. Only for Online Gaming participation, Fisher's exact test yielded $p < 0.001$, suggesting participation to this activity is significantly differed by gender. Although, these results do not indicate any gender difference, while conducting the interviews we observed a trend where male participants seemed to prefer Laptops or Tablets for most of their activities, while female participants seemed to prefer Smart Phones. For example, a member of F1 (Only Daughter, Age:21) remarked:

"I do everything...chatting, facebooking, amazon... on my phone, I like one hand typing, its quick, and the phone is always with me..."

Similar expressions from multiple other female participants suggest that Smart Phones are popular due to portability, quick accessibility, multi-purpose functionalities and for not demanding dedicated computing time. A member of F18 (Wife, Age:33) expressed:

"My iPhone is always with me, and it has everything that I need, and I do not like sitting in front of the laptops..."

IMPLICATIONS

The results we have presented offer a detailed picture of how different devices are used in a domestic environment for online activities. In this section, we discuss the implications that emerged from our study that we found most compelling.

The Transformation of Desktop PC

The increasing availability of mobile devices has certainly changed the role of Desktop PC in domestic environments. We can now look back on the 1990's as an era in which the Desktop PC entered the home and began to modify domestic practices and family life in fundamental ways. This role has completely being overtaken by the Tablet and Smart Phone. Our study clearly showed that the Desktop PC is becoming

a niche platform primarily used for dedicated applications, e.g., Gaming, Music Composition, etc., albeit still being the most powerful and multi-purpose device in the home. This is very much a sign of changing social context of how computers are used in the home. The combination of portability (also observed by Nylander et al. [15] as a key reason for use of mobile phones at home), multitasking and communality offered by mobile devices, has clearly shifted computing practices in the families, and has changed the way they interact with different applications. While we do not advocate completely ignoring the Desktop, designers of future technology and applications intended to be used at home should pay particular attention to mobile platforms, especially for applications intended for shared use.

Activity First, Device Next

A plethora of multi-purpose computing devices are now available in our homes. It might be expected that the benefits of each device alone might drive its use. While device capabilities are certainly important, our study showed that it is not simply a function of what one can do with the device that dictates the use. Instead, both the nature of the planned activity (e.g. interaction type, length, etc.) and the surrounding usage context (physical setting, need for multi-tasking) in which computing activity occurs that drive the selection of a device. For serious activities like working from home, it is natural that people prefer established working platforms, e.g., a Desktop PC or a Laptop. However, for light weight activities e.g., Social Networking or Online Shopping, the nature of the activity (e.g. shorter interaction) influences people's selection of device. For example, for skimming through Facebook or Amazon people tend to prefer mobile devices, e.g., a Tablet or a Smart Phone, but whenever they need a longer interactive session, they prefer to switch to a more powerful platform like a Laptop. Usage context of the activity also plays an important role, e.g., we saw that communality and multitasking factors influence people's Video Watching activity. For video watching, small form factor mobile platforms were more popular than we expected for shared use. Our findings suggest domestic technology designers must assess the larger context of the activity they are enabling to inform their design decisions, for example, the amount of commonality, expected physical setting and the expected length of the interaction.

Less Contention, More Personal Spaces

As a natural consequence of the availability of many devices, both fixed and mobile, we have not seen any contention for devices in our study. This is in sharp contrast to previous research that indicated heavy contention over family computers [11]. This clearly indicates how the social context in which families do online activities has changed over the years due to prevalence of mobile devices. However, this personal usage also introduces ad-hoc private computing spaces in the home. In our study, many of the participants mentioned that often they create an *invisible shield* spontaneously around them while using their mobile devices. These momentary isolations often happen when they are in the *hang-out* spaces (as termed by Mateas et al. in [14]) like in the Living Room or

Kitchen. Interestingly, they also mentioned that sometimes these small interactions with their mobile devices led to long sessions in front of their Laptop. We see interesting dynamics emerging here, e.g., while in the past contention was often common for computer time, it also meant people used to have more free time for their families as they had a finite number of opportunities each day to use the computer and go online. With more and more devices in the home, people can use the Internet deliberately anytime often in small fragments, however this deliberate use often comes at the expense of time spent on other leisure activities in the home.

The Role of Applications

As previously mentioned, a number of participants reported they prefer particular applications, e.g., Facebook, Amazon, and EBay on mobile platforms as user experience is much better. While this is remarkable, we also observed that these applications required minimum typing and mostly served contents for viewing. These observations are interesting because one might expect the desktop versions of these applications with larger frames and more tailored functionalities to be preferred to constrained mobile versions. However, our study showed that a well designed mobile user interface that minimises fragmentation of attention [7] and offers limited but objective application functions (e.g., push notification) can significantly improve the user experience, even to the extent that it drives the user's preference to a dedicated device.

CONCLUDING REMARKS

In this study, we highlight changes in the use of computing devices in a domestic environments. By examining the computing dynamics in 18 homes in northwestern Belgium informed by a larger survey and logging data collection, we uncovered insights around people's preference for devices, times, and locations to engage in six common Internet activities. Certainly, the results presented here must be interpreted in the context of the culture and infrastructure in which they were collected. We expect our results are most appropriate for designers of future domestic technology in Europe or countries with similar cultures and levels of technology adoption.

With increasing number of mobile devices in our homes, we are observing a metamorphosis in how computing practice is domesticating itself within existing patterns of family life. By examining the device, spatial and temporal aspects of home computing and their relationship to common Internet activities, our aim is to raise awareness of the importance of multiple facets of home computing use. Our findings highlight the way home computing has truly become unplugged, leaving behind the few favoured places in the home where people used technology in the past to spread out throughout the home into new locations.

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