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# How to apply IoT skills at home: Inequalities in cultural repertoires and its interdependency chains

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## ABSTRACT

Using the Internet of Things (IoT) at home is promising but also a conduit for new digital inequalities. People start using IoT in different ways, ultimately determining the outcomes, benefits and exploitations of IoT use. Typical for IoT use is that everyday activities involve more parties, internet connections and internet services. IoT is socially embedded in a network of interdependencies and power balances between different parties. Through qualitative research interviews and house tours among 30 households, we examine how people start using IoT differently and how they position themselves in relation to others in doing so. We adjust operational skills and collaboration skills from a digital skills framework to IoT and construct choreographic skills to address the socio-materiality of the IoT. We find that collaboration skills to increase the effectiveness of IoT use generally relate to cultural repertoires coupled with higher education, whereas choreographic skills to increase the efficiency of IoT use is coupled with an alternative repertoire that utilizes skills outside of higher education. Self-reliance, consequently, is an important distinguishing value for a cultural repertoire coupled with lower education.

## 1. Introduction

Internet of Things (IoT) is a network of everyday devices connected with the internet ranging from doorbells, lights, and thermostats to activity trackers, exercise tools, and heart rate monitors. The IoT network can help individuals reduce their energy consumption, live healthier lives, and secure their homes by enhancing conventional physical world objects with web-based services (Kulkarni & Sathé, 2014; Rayes & Salam, 2018; Van Deursen & Mossberger, 2018). Consequently, IoT networks show tremendous promise for skilled users, yet it can be a conduit for new digital inequalities for lesser skilled IoT users. As such, IoT skills proliferate effectiveness and efficiency in its everyday use (De Boer, Van Deursen, & Van Rompay, 2019; van Deursen & Mossberger, 2018). In this contribution we take three steps to unravel how the social context at home stimulates certain skills over others for IoT use.

We begin by examining how straightforward household activities become involved in an expanding IoT network of interdependencies with organizations and stakeholders. For example, IoT can automatically shut down the central heating when you leave your home, but to do that it needs a stable WiFi-connection and internet service, extracted data (for geofencing) from utility

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companies and IoT manufacturers, and operating software (mobile applications) with an operating device (e.g., smartphone). That is, in the words of [Elias \(1983 \[1969\]\)](#), interdependency chains become longer with IoT use. Organizations and stakeholders in these interdependency chains however, pursue goals that may contrast the goals of IoT users. IoT data, for instance, can strategically be implemented to construct more profitable deals for utility companies or insurance companies ([Mandl et al., 2015](#); [Shah et al., 2019](#)), streamline healthcare and insurance costs ([Kulkarni & Sathe, 2014](#)), or increase security and control ([Hoque & Davidson, 2019](#)). New forms of digital inequalities, in effect, emerge from the power balances between interdependent parties involved with everyday IoT. Therefore, from a user-perspective, we first need to ask:

RQ1: How are interdependency chains established by IoT users?

Consequently, we need a greater understanding of people's ability to act upon power balances within interdependency chains. People, generally, have different tools in their cultural repertoires to call upon when required (([Swidler, 1986](#)); [Lamont et al., 2010](#)), and these cultural repertoires provide them with possible modes of action and meaning ([Hannerz, 1969](#)). Moreover, a greater diversity of repertoires place people in a better position to situate their actions ([Garret, 2016](#)). Previous research on digital inequalities has shown that digital skills can be regarded as such cultural tools that contribute to beneficial internet use (e.g., [Hargittai, 2015](#); [Van Deursen et al., 2011](#)). While proficient IoT use is likely to follow the same trend ([Van Deursen et al., 2019](#)), less is known about the social context to provide a meaning to stimulate and develop digital skills. In the current contribution, we propose that interdependency chains could explain why some digital skills are stimulated in cultural repertoires of action where other skills are not. For instance, skills to store and protect IoT data become redundant with third-party assistance, while skills to manage home networks become important when household members need assistance. Therefore, we ask:

RQ2: How do interdependency chains influence which digital skills are used?

Lastly, research has strongly coupled internet-related skills with higher education (([Hargittai, Piper and Morris, 2019](#)); [Van Deursen et al., 2011](#)) and higher educational institutions give considerable attention to the repertoire of skills that involve digital information, internet communication, and strategic internet use ([Davies & Eynon, 2013](#); [De Haan & Huysmans, 2002](#); [Van Deursen et al., 2011](#)). While survey research has continued to couple IoT skills with cultural repertoires of education ([Van der Zeeuw et al., 2019](#)), we are interested to add alternative cultural repertoires for IoT skills. As those with lower levels of education are constrained in the diversity of their cultural repertoires ([Garret, 2016](#)), selective sampling by educational level can give us a better understanding of different approaches in digital technologies ([Scheerder et al., 2020](#)). A sensitivity to alternative repertoires can give a more saturated understanding of IoT skills and its potential for emerging digital inequalities. Therefore, we pose our third research question to explicitly engage lower educational repertoires in interdependency chains of IoT use at home:

RQ3: How are interdependency chains coupled with lower and higher educational repertoires when starting to use IoT at home?

With this final step we employ education as a sensitizing concept ([Blumer, 1954](#); [Denzin, 2017 \[1970\]](#)) to guide our findings towards alternative repertoires of action; specifically aimed at skills outside of the direct educational repertoire. Through abductive analysis ([Tavory & Timmermans, 2014](#)), we examine the social context in which IoT is being used, while being systematic in our approach to the literature on digital inequalities. We begin by describing our methodology to emphasize this reiterative process between theory and data from which our analysis emerged.

## 2. Method

In 2019 we selected a theoretical sample of 15 higher educated and 15 lower educated<sup>1</sup> participants in the Netherlands, with IoT devices currently being used in their household. Our recruitment strategy was mainly targeted at lower educated IoT-using households to compensate for a difficult-to-reach population for social research. We recruited with flyers and four schools cooperated with a request to distribute our recruitment letter via parents' newsletters. During the later stages of recruitment, we hired a recruitment agency and used a snowballing method amongst participants that already signed up.

Participants were invited to sign up via a website that explained our study. To apply, participants had to fill out a form with their name, contact information, and level of education. We limited our social categories to educational level to restrain our assumptions of predefined social groups and emphasize group formation instead ([Latour, 2005](#)). The participants were also asked to fill out which IoT devices they currently used in their household, our main selection criteria, and if they used any other IoT devices like smart watches or activity trackers. In our selection we prioritized household IoT devices because we found that most IoT users have health-related apps or IoT devices. Aside from educational level and IoT devices we aimed for a diverse selection of participants to improve a theoretical saturation on IoT use at home. This includes figurations of household size, amount of IoT devices, rare types of IoT devices, innovative IoT set-ups, neighboring participants, colleagues, or (extended) family members.

All 30 household visits and interviews have been conducted by the first author. The visits started by repeating the aims of the

<sup>1</sup> Lower educated: Participants with no more than a Secondary Vocational Education.

Higher educated: Participants with Higher Professional Education or more (e.g. college or university)

research as stated on the recruitment website, how we handle their input as sensitive data, and emphasized that participants could stop their participation at any moment during and after the research. Participants were asked if they had any questions or concerns about the research and were asked for permission to record the interview using a GoPro Hero 7 (for audiovisual data). The interviews started with a house tour (Brown et al., 2015, Mitchel et al., 2015) where participants were asked to introduce and show their devices, device placement, and mobile apps they used. Participants guided the researcher through their devices, sometimes quickly demonstrating the main buttons or the accompanying mobile application. During the remainder of the interview, participants were stimulated to 'show and tell' (Woodward, 2007) and to offer short re-enactments of their device usage (Pink & Mackley, 2014). The introductory house tours and added visual component during the interviews were designed to keep the interview open for the free flow of conversation while supplemented with structured interview questions.

The interview questions were structured according to research topics on internet domestication (Berker, 2005) and digital skills (Van Dijk & Van Deursen, 2014; Hargittai & Shaw, 2015). Participants with children were asked about learning practices in parental mediation (Plowman, 2014; Ito et al., 2009) to address the influences of children when people start using their IoT devices at home. However, most participants found their children too young or not interested in IoT. Influences of family and friends were inspired mainly by social learning in supportive networks (DiMaggio & Garip, 2012) and whether participants are surrounded by 'warm' experts (Bakardjieva, 2005) or those critical of IoT use. Lastly, we turned to the supporting role of organizations and manufacturers when participants started to use IoT at home. A detailed interview protocol can be found in Appendix A. At the end of the interviews, participants were asked if they had questions about the interviewer, the research, or if there was anything else they would like to address. Interviews lasted on average 43 min (Min = 24, Max = 72), depending on the complexity of the smart devices and IoT system used.

The audiovisual data have been transcribed, coded, and analyzed with Atlas.ti. Initially, the data were organized according to a closed coding scheme derived from the interview structure constructed beforehand. This data familiarization phase was followed by a more in-depth analysis attentive to gaps in existing theory and surprising findings (Tavory & Timmermans, 2014). Next, an inductive procedure with a main focus on circulating incidents and cases (Glaser & Holton, 2004) was used to keep the analysis grounded in empirical data. Finally, extended memos were compared with relevant literature to substantiate our empirical findings with the theory discussed below. We use pseudonyms for the participants quoted in Section 4. Quotes have been selected because they are concise and insightful without disclosing too much personal information.

### 3. Theory

With IoT, people become dependent on one another in different ways from before. Interdependencies flow between IoT users, other family members, companies and service providers, and others with maintenance responsibilities. In the advancing network society (van Dijk, 2012), IoT can be considered a medium for generating a dynamic and complex system. Such a system is characterized by individuals who are tightly coupled with one another and with the natural world, while accessible information is limited and ambiguous (Sterman, 2006).

To gain a better understanding of how IoT is being integrated digitally and socially in a dynamic network society, we turn to the work of Elias (1983 [1969]) on interdependency chains in social figurations. Figurations are the changing pattern of how people relate to one another, socially and physically. This pattern creates a 'flexible lattice-work of tensions' between allies and opponents who are dependent on each other within such a figuration. As figurations become more complex, interdependency chains tend to become longer and more divided. Consequently, interdependent relations of mutual benefit and competition shape how power balances shift between parties (Goudsblom & Mennell, 1998; Kuipers, 2018). By extending this social tug-and-pull to IoT, Elias helps us to obtain a perspective on digital inequalities and IoT use, where individuals are exploiters and exploited simultaneously but with different proportions of power.

Digital inequalities have been considered on three levels. The first level concerns physical or material access and typically distinguishes between *haves* and *have-nots* (Van Dijk, 2006). The second level digital divide focuses on a repertoire of technological skills and uses (Hargittai, 2001) and the third on outcomes (Wei et al., 2011). Research has shown that digital skills are implemented as cultural tools by their compound and consequential effects (Van Deursen et al., 2017). Moreover, digital skills are frequently linked with higher education (Hargittai et al., 2018; Van Deursen et al., 2011) and educational repertoires (Davies & Eynon, 2013; Robinson, 2018; Scheerder et al., 2020). While the variation of digital skills is extensive (e.g., Van Laar et al., 2017), they do not automatically translate to IoT (Van der Zeeuw, 2019). Our theory, then, follows the empirical peculiarities of IoT through abductive analysis by which we emphasize the more prominent skills when people start using IoT. Here, operational skills used to set up IoT systems are considered a starting point to study IoT use. To obtain advanced services and support from third parties and increase effective IoT use, however, collaboration skills become more influential. Collaboration skills have been used to describe digital teamwork skills towards a common goal (Van Laar et al., 2017), but with IoT these skills underscore the conflicting goals between parties while they are collaborating. Additionally, choreographic skills emerged inductively to describe the skills used to adjust physical space, social space, and time available to increase efficient IoT use.

#### 3.1. Operational skills are considered the starting point for using the internet and internet connected devices

Operational skills refer to a set of technical competencies and user control (Van Deursen & Van Dijk, 2011), mostly with regard to the different layers of digital technologies such as drives, folders, files, scripts, and programming in a basic 'if-this-then-that' structure. As consumers start using IoT, operational skills are used in the initial setup of IoT devices. After the initial setup, one of the

more notable features of IoT is that it works autonomously and unnoticeably (Van Deursen & Mossberger, 2018). However, operational skills are used with different levels of sophistication. For example, a new IoT device can be installed simply by pushing a button on a gateway that automatically recognizes the new device within the same digital radio network. Setting up multiple devices of different brands and services while integrating them into a single operating system requires considerably more effort. More advanced and personalized IoT systems even require programming skills to work fluently. Therefore, prolific or absent operational skills are important to establish the interdependency chains involved and how power balances are distributed for continuous IoT use.

While education has a positive effect on operational skills, these skills are often acquired and developed outside of educational settings (De Haan & Huysmans, 2002; Van Deursen et al., 2011). Moreover, operational skills are generally taken for granted in education, even though variation in such skills does exist (Ng, 2012; Hargittai, 2010). This notion gives the important realization that the use of the internet- and internet-related skills is not uniform (Bennett et al., 2008). A similar pattern can be expected when setting up IoT systems, especially for the more advanced operational skills that require programming.

### 3.2. Collaboration skills describe social competencies that consist of being able to ally with third parties to help install complex IoT hardware and software, to store and protect data, or to use advanced support and services that sufficiently improve IoT use according to personal needs

It also means being able to compromise and tolerate the conflicting goals that can be pursued by the parties involved. Unique to IoT are the continuous or subscription-based services provided by organizations (e.g., utility companies and manufacturers) for everyday use, for example, by regularly updating their IoT devices, storing data, and analyzing data to help consumers strategically use IoT. Having good collaboration skills is crucial because IoT is vulnerable to vendor lock-in (Roman et al., Lopez, 2013). That is, consumers can become locked-in with manufacturers because they are dependent on the software and services needed to operate their IoT devices on a daily basis. Additionally, consumers can become locked-in with manufacturers when they aim to upgrade their IoT systems with new devices because brand-specific connection hubs and gateways do not communicate with off-brand devices.

Moreover, collaboration skills can turn to proxy use by third parties when other skills are lacking (Reisdorf, Axelsson, & Maurin Söderholm, 2012) Eynon & Geniets, 2016; van Deursen et al., 2014). Proxy use of IoT can range from professionals installing smart thermostats or medical professionals interpreting biometric data via wearables to neighbors assisting in setting up an IoT system. As such, collaboration skills provide a viable strategy to be less involved with the initial setup of IoT devices or maintaining an IoT system, but it does increase a dependency on other parties.

While uniquely directed at the IoT, collaboration skills are influenced by underlying internet-related skills that involve understanding what information is being collected and who has access to it. Educational level is an important resource for developing such skills, with increasing significance for data literacy and protecting privacy (Van Dijk & van Deursen, 2014). Lamont, 2009 describes that collaborative orientation is an esteemed personal value among higher educated individuals which stands in sharp contrast to the cultural repertoires of the working classes, who are more easily frustrated by a dependency on others and favor self-reliance. Overall, it will be easier for the higher educated to access collaboration skills as part of a cultural repertoire.

### 3.3. Choreographic skills refer to a set of embedded competencies to adjust physical and social space to IoT devices

Whereas collaboration skills are coupled with higher educational repertoires, choreographic skills poses an alternative repertoire for IoT use. Inspired by Loke & Kocaballi, 2016 sociomaterial framework on the domestication of technology, choreographic skills consist of three main components. First, being able to fit IoT devices within a preexisting material structure with other domestic technologies. The general conception is that the material properties of devices influence their potential use (Latour, 1992). For example, by keeping wires and other small items off the floor so that robot vacuums can run without supervision (Sung et al., 2007). Additionally, the relation between IoT devices and software updates continues to enhance devices, which are otherwise relatively static in their use, and affects their placement potential.

Second, being able to use IoT (devices, apps, and accounts) with multiple people. People are choreographed by the social formal and informal rules of conduct that describe who has access or participates with IoT use depending on expectations for the primary functions of the device (e.g., Loke & Kocaballi, 2016; Plowman, 2015; Bakardjieva, 2005). For instance, Rainie and Wellman (2012) argue that more choreography is needed when computers are shared, and therefore, several email accounts are created to keep messages separate. IoT devices and related mobile applications are similarly shared within household ensembles, and users need to tie multiple accounts together to share IoT devices.

Third, being able to fit IoT within existing patterns of behavior. People are choreographed by their possibilities of movement in terms of effort, motivation, and time. For example, wearables and biometric data motivate people to become more active and schedule daily exercises accordingly, keeping them in a technological loop (Parviainen, 2016). That is, choreographic skills are used to fit IoT with the time and effort available.

Choreographic skills specifically address IoT as systems with extendable hardware and software features that change how the IoT is being used over time in social and material dimensions. Thus, where operational skills are used to set up IoT, choreographic skills are used to increase the added value of an IoT setup and use it efficiently in a social context.

## 4. Findings

### 4.1. *The IoT as a medium of interdependencies*

When IoT devices connect with the internet, they enhance everyday devices with internet services. It makes IoT at home a medium that gives material means to internet services. Consequently, individual users are continuously dependent on manufacturers for the everyday use of their devices. Manufacturers are tied to their customers longer after the initial sales of their products because the information-driven economy makes user data a valuable resource.

To gain an understanding of how interdependency chains influence how IoT skills are stimulated as cultural repertoires of action, it is important to first consider the material means of IoT services. What follows is that IoT systems are set up differently to enhance or restrict interdependency chains, and power balances shift accordingly. The dependency on IoT services becomes apparent when users, such as Alfred, question whether devices work without support. As Alfred explains:

Well, my [smart] lock, for example. Suppose that tomorrow the manufacturer goes bankrupt or something. And then? Can I still use it or do I have to throw it out and buy another one? So, the usability depends on the manufacturer, it feels like. Maybe I can still use it with the app. But it feels like the manufacturer actually decides how long such a product can be used. Also, for how long does it remain profitable for a manufacturer to continue support with such a product? When they stop supporting, then you'll just have a problem. Then, I have a worthless thing.

Alfred's concerns highlight the material basis for services in profitability for the manufacturer and tied to the usability of the device itself. Without the skills to rewrite the software and make the IoT work locally, there is a continuous risk of being locked-in with manufacturers who maintain IoT software. Nevertheless, being locked-in is not one sided, as mediated services can enhance smart products even further. An illustration is given by Peter, who has a smart doorbell. This doorbell includes a camera, sends mobile notifications when someone rings the bell or appears in front of the camera, and makes live video accessible with an app on his mobile phone. Peter explains the added value of a subscription:

They are very clever by giving you the first 30 days for free, free in parentheses, to store the images, and after 30 days they ask if you want a subscription so that all the images are stored longer. That was a consideration for me not to do it, the Ring [doorbell]. But in the end, with all the other advantages, I said yes. Then you pay 30 euros a year, I think, and get a subscription that includes everything. I kinda felt like that would be the best option. And then I also consider it as a piece of security. That is, how I could justify it for myself. Because at first, I had something like, for only the doorbell? I was like: "mmh, mmh." But if you look at it a bit broader, then it is not so bad. And then your images are saved and you can see something back again.

In exchange for an annual subscription, the function of a doorbell can be enhanced to function as a security device. It saves Peter from having to store data and secure it digitally on a private server. More importantly, by having control over storing and protecting sensitive data, it increases the power balance in favor of the manufacturer, who then also has control over it and will use it for different goals than Peter.

In contrast to enhancing features, the constant mediation of IoT can also be disruptive. Even when most of the maintenance is in the hands of IoT users themselves, software constantly evolves through updates. Some people, such as Robert, start using IoT and become more actively engaged. Robert considers it a hobby to integrate extensive IoT systems; this integration, aside from searching for a cheaper alternative to IoT devices, consists of actively personalizing software. However, IoT devices are still tied to software updates, for instance, to improve the stability of the software. These updates can be quite disruptive, as Robert explains:

Sometimes with an update, it might not work for a while. Then I'll have to see where it comes from. Sometimes they change things a little bit. Then you'll have to ask questions differently in the system. Yeah, then they have changed something which makes you have to set your own script a bit differently. But usually it's only a little while before it works again. Well, an update in the morning, that can be bad. Certainly if you have to go to work. That's when it doesn't work for a little while longer. It also depends on what it is exactly. Sometimes it can take a while but no longer than an hour.

As a result, when Robert has not updated scripts because he is out at work, it means that other family members are without working lights in the morning. Or, they are not being notified when windows are still open upon leaving. The habitual dependency on IoT working properly also mediates a dependency on maintenance. Meaning that without the reliability that third parties offer, IoT systems can be less stable and more easily disrupted. Moreover, while the power balance favors Patrick in storing his own data and writing his own scripts, his IoT system still mediates interdependencies with other parties who occasionally want to improve their overall software stability.

### 4.2. *Interdependency chains when lower and higher educated start using the IoT*

As described in the previous section, how people start using IoT is partly determined by material means of IoT services and how the IoT has been set up. Based on our empirical data, Fig. 1 shows an interdependency chain of an IoT system at home ranging from service providers and manufacturers to IoT devices, IoT users, and the homes where the IoT is set up with its co-users. We now turn to

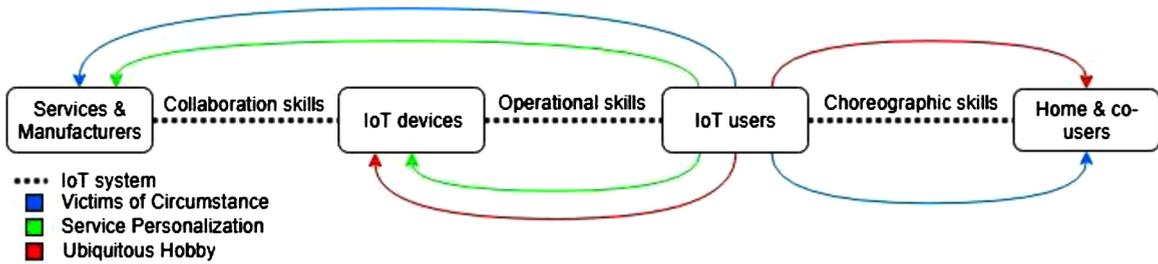


Fig. 1.. Interdependency chain of the IoT system at home.

our second research question: How do interdependency chains influence which digital skills are used?

Our empirical findings suggest three alternative interdependency chains shown in blue, green, and red in Fig. 1. The chains are based on compensation strategies that emerge from applying operational, collaborative, and choreographic skills shown in Table 1. First, the chain *Victims of Circumstance* illustrates the ubiquitous penetration of IoT in everyday life as the most common type of IoT use. The influence of educational repertoires is limited in this chain due to its circumstantial character, and power imbalances appear to be hidden to most users. In the chain of *Service Personalization*, users are working in alliance with service providers to maximize effectiveness. However, there is also much exchange with third parties in terms of personal data and security, intensifying an interdependency between services and user-generated data. This is an interdependency chain that relies on a cultural repertoire typically associated with higher educational levels. In the chain of *Ubiquitous Hobby*, most of the responsibility is on the main IoT user at home for maintenance and ease of use for other family members; an alternative cultural repertoire that is more accessible and typical for the lower educated. Users in this interdependency chains have a relatively high proportion of power relative to service providers and manufacturers but are also left without advanced services and benefits to make their IoT use more effective.

#### 4.2.1. Victims of circumstance

As everyday devices break down and are replaced by IoT devices, many are introduced to the IoT by circumstance. Mobile phones come with preinstalled health apps waiting to be discovered. Or, people move into newly built houses with a 'smart' infrastructure for power plugs, solar panels, and thermostats connected with the internet. Generally, this infrastructure is a casual use of IoT where individuals have been assisted in their process to start using IoT, and therefore, the influence of education as a cultural repertoire is limited. Simply put, the IoT has been skillfully fitted within choreographies of daily life by collaborating with other parties.

What characterizes this chain of IoT use is its dependency on others for operational skills. For instance, when IoT devices are installed and maintained by a mechanic, as is the case of Mike, who "believe[s] that the thermostat is linked with the email address of the mechanic, also in the case of any malfunctions." Consequently, when pressure in Mike's boiler falls below a certain threshold, his mechanic is automatically notified. This type of use can be expected from the IoT, as it aims to work invisibly after it is set up and operational skills are less prioritized in continued use (Van Deursen & Mossberger, 2018). Moreover, lacking operational skills for the initial setup can have a deterring effect on IoT use. Roza, for instance, is very capable of using smart light settings, including a disco-mode that reacts to sound for her children, and knows where to place her lights to make the most efficient use out of it. However, in regard to more technical operational skills, Roza explains:

**Table 1.**  
Interdependency chains when lower and higher educated start using the IoT.

	<i>Operational skills</i>	<i>Collaboration skills</i>	<i>Choreographic skills</i>	<i>Educational repertoire</i>
■ Victims of circumstance	-	+	+	Higher and lower
■ Service Personalization	+	++	-	Mostly higher
■ Ubiquitous Hobby	++	-	+	Mostly lower

+ = required, ++ = strongly required, - = not required

I can't use it as well as my son and my partner. The connecting and that stuff, that would not work for me. No, I'm not that handy. If I had been alone with my children, I would not have bought it. Maybe I would have asked my father if I really wanted it. But then you don't purchase it because you have to bother someone for the installation. So, I would not have bought it myself. To install all of that and how it all works, no. And yes, I get frustrated when things don't work and he's not here, then I'll call him.

Individuals such as Roza are perfectly capable of using IoT in their daily life and making choreographic adjustments but rely on collaboration skills, knowing who can install IoT for her and where to find help, to get over operational thresholds. With ongoing support in social networks or proxy use, informally by friends and family or formally by manufacturers and mechanics, having good collaboration skills can be used to compensate for lacking operational skills.

As the IoT has been made to fit into the choreography of daily routines with the help of others, more advanced operational functions are neglected or remain undiscovered. This outcome is what happened to Luke, whose smart thermostat was installed three years ago. Luke finds that turning the heating on and off with his app is such an easy procedure that other functions were not discovered until the interview:

[I've] no need for a program, so I didn't really get into it. ((Picks up his phone)). I see you can monitor all sorts of things. Energy consumption? Oh, that's new to me. Oh, I can even see the use of gas this week.

Operational skills, while perhaps not absent in Luke's cultural repertoire, are not stimulated or needed within such a chain of interdependency. After the installation, Luke's choreographic skills bypass the need for operational skills and more advanced functions. Consequently, the absence of operational skills impairs strategic use of IoT, as Luke has not been monitoring his energy consumption. However, this absence does not mean that those without operational skills are without strategic benefits of IoT. In fact, no requirement of having operational skills is part of the attraction for using IoT. As Elise explains, well-implemented IoT devices help with the cluttered choreographies in daily life:

In the beginning, we had some difficulties with our lamps because we simply forgot about them very often. And then I would get another message from him saying: "you have forgotten the lights upstairs again." So yes, I think it is very handy that we have [smart] lights. Also, with the [smart] thermostat. If you no longer have to think about something because it happens automatically, then you have more space to think about other things, like groceries or something. I think you have more room in your head. Also, because you can do so many things with the internet that you don't have to think about everything anymore. I sometimes like that. And then I can happily focus on my children, or on my work. Then, I'm really at work.

For Elise, IoT helps with household responsibilities while she is occupied with other tasks. Moreover, IoT can offer cognitive elevation from everyday clutter and stress. In such interdependency chains, it can be a greater advantage to not having to use operational skills than it is a disadvantage of not having them.

#### 4.2.2. Service personalization

At first, IoT devices allow people to obtain similar devices more easily because only one bridge or gateway is needed to connect those devices with the internet. For example, one smart light is a motivation to get more smart lights because there is already an IoT structure in place. Other times, people become familiar with health apps on their phone, and they want more features or better accuracy with wearable activity trackers. In other words, with good collaboration skills, they seek manufacturers and companies to match their operational skills and personal needs. By utilizing specific mobile applications, certain functions are more advanced. However, specific apps are generally not integrated into one IoT 'ecosystem'.

With an interdependency chain between collaboration skills and operational skills, the difficulty is in getting a system that becomes choreographically autonomous. The Service Personalization interdependency chain is characterized by each user having its own responsibility on how he or she uses IoT. Devices are set up and apps are installed but not used by everyone. This lack of use can cause some confusion as to which apps and devices are coupled, as shown by Mary during the interview:

We don't have a Google home or something. Let me think, yes, part of that is also in this one app. What is that called again... ((Picks up the phone)). I think it's in the [...] app. I think that one can do things... Like show your lights and stuff. Well there are a number of things, that's what makes it a bit tricky of course. That you have a number of apps and not a single app that can do everything. I'm just thinking, because there should be an app that you can also use to do the lights and the heating and all kinds of things together. But I just don't use it, so I don't know what it's called. ((Puts the phone down)).

Specific apps advance service personalization and provide collaboration benefits, but it also establishes a dependency on service providers and manufacturers. Such interdependency chains are broken when using alternative software to tie apps and devices together. Therefore, choreographic skills to fit an IoT system into their lives are less prevalent. Tying multiple apps and devices together requires effort, motivation, and time that is not available to everyone.

Moreover, as household members are individually responsible and capable of their own IoT use, it becomes more apparent that nonusers are disruptive to IoT. For example, a household consisting of two higher educated individuals with good operational skills, Ellen and Kevin, describe sharing their IoT at home with a housekeeper that has no interest in developing operational skills:

We have a housekeeper in the morning once a week. And then in the morning I am sometimes confused about why the lights don't go on. Well, of course... But yes, she may turn the lights on as well, only she does not have the app to turn them on differently. We can't let her work in the dark, no, so when we go on a holiday and we don't want the light to turn off with the switch, we put some adhesive tape over it. So, it can't be turned off or on.

Ellen and Kevin's lights are set up to simulate living when they are on holiday to provide a sense of security. This is a preset function on the app that comes with the lights. However, this function does require that old fashioned light switches, which Ellen and Kevin hardly ever use, remain switched on. As their choreographic skills are at a lower level for figuring out access for multiple people, an impromptu solution became adhesive tape.

Similar to security settings on smart lights, people seek out devices specifically for IoT services. As the case with Cassian, whose installed smart thermostat helps monitor and eventually reduce gas output. As it is more common among higher educated individuals to be skeptical about internet use and privacy (Scheerder, van Deursen, & van Dijk, 2019), Cassian's selection was influenced by his weariness of intrusion by large corporations and concerns of what is being stored in the cloud and where:

Well, the reason that I have chosen to install Tado is that it is a European company. It is based in Germany. And they also say that all data are stored within Europe. That they meet a certain security level, certain ISO standards for data security. And you know that they also use the data anonymously to improve their entire ecosystem.

Cassian also based much of his knowledge on privacy on peer testimonies of friends who work in ICT. Meaning that he acquired some of his information informally by other higher educated individuals, a common effect of homophily of social networks in social learning (DiMaggio & Garip, 2012). Cassian, however, stumbled on a choreographic problem because he already had a floor heating system installed on both levels and wanted to use Tado only on the ground level. As the existing material structure does not match the IoT qualities, Cassian explains:

Well, tried it twice [with the Tado helpdesk], and it failed twice. They said: 'What you want is not possible or you should buy thermostat faucets for 100 euros each.' With five groups, I think that's a bit too expensive. So, with Arduino, a programming board, I have programmed an if-this-then-that program. So, the moment I have a heat demand here, Tado sends a signal to the boiler: there must be hot water. But what it actually does is give Arduino a signal that it needs to get warm in the living room.

Rather than keeping Tado out of his IoT system, Cassian relied on his operational skills to make it work while continuing to use the monitoring services of Tado. For the future, however, Cassian wishes to create a more extensive IoT system that fits his personal needs. He continues to develop operational skills but is beginning to look towards open-source alternatives to use IoT devices.

#### 4.2.3. A ubiquitous hobby

The initial IoT setup quickly becomes an ongoing activity when IoT devices keep getting added to an IoT ecosystem. IoT usually uses ZigBee, a digital radio network that allows for wireless communication between devices. To connect the IoT devices with the internet, companies have their own bridges or gateways, which also restrict devices from other companies to tap into the same network. Theo, after first using lights by Philips, saw on YouTube how to connect Ikea lights in the same network. He explained that he could use ZigBee2mqtt software on a usb-stick to bypass bridges or gateways from companies and control ZigBee devices directly. Adding devices and managing the IoT system in his home has become somewhat of a hobby since then:

I have everything on one system now, so I no longer need different gateways. I enjoy that. I can manage everything myself and adjust it to my needs. And then, it depends, sometimes I am busy for a whole week reinstalling everything, setting everything up. Other times I leave it for a month as it is. So it's just when I get new ideas about what I want to change. Now I have bought a Raspberry Pi. Just need to think about what I will do with it. I still have to flash it [the SD drive] and put other software on it. And then I have to find a place where it is handy to use it.

Theo shows that his choreographic skills are continuously needed in tandem with his operational skills. Advanced operational skills increase the flexibility of using devices for different functions and, in effect, create different possibilities for daily life choreographies. Additionally, Theo shows an interest in new devices for operational use first and using it choreographically second. Most of the skills to establish a network of devices that is stable and protected are self-taught using peer-to-peer internet communities. Moreover, collaboration skills are hardly used in this interdependency chain, and they tend to fall outside the boundaries of a higher educational repertoire. Instead, self-reliance, as shown by Theo, is an esteemed alternative moral worth (Lamont, 2009). IoT gives users such as Theo more autonomy and control instead of less, as predicted by Van Deursen and Mossberger (2018). While considered a hobby, it remains a priority to make it easy to use for their partners and children who tolerate their IoT enthusiasm "as long as everything works", socially and materially.

Consequently, as IoT users in this interdependency chain aim to be more self-reliant, others turn to them for help. This is the case for Jonathan, whose repertoire of digital skills have created such a reputation among his friends and family, that "if they have a problem and are unable to fix it then I am often one of the first to be called." When asked if he enjoys or dislikes it when others ask for help, Jonathan laughs:

Hee-hee, no I do enjoy it somewhat. I'm just too helpful and I think it's just something you do for friends. But sometimes you do think that maybe I should ask something for it. It also depends on the problem, and you get better at being able to analyze what makes sense to solve and check.

Operational skills have made Jonathan a dependable figure for problems related to the internet and IoT. In this chain of interdependency, users are often asked for help by others but also tend to be a little wary not to become their “personal helpdesk”. A sentiment close to Bourdieu (2001: p. 174) insofar as the dominant are dominated by their own dominance.

## 5. Conclusion

### 5.1. Main findings

While some choose to start using it, the IoT can happen to anyone. Whether via biometrics and health apps that come with a smart watch or the boiler stops working and with its replacement they find themselves connected to an IoT network. Following digital inequality research, skills are expected to be crucial in transforming IoT use into tangible outcomes. Foremost, Elias' (1983 [1969]) framework has provided us with a better understanding of how interdependency chains determine what skills are required or stimulated by compensation strategies and composites of other skills. As IoT mediates interdependency chains, users cope with varying degrees to being locked-in with manufacturers by enhancing services via subscription formats and adding functions or by trying to reduce the degree that mediation is being disruptive to their IoT setup. Continuing our analysis, we can draw two main conclusions based on the selection of skills used in the interdependency chains we identified.

First, Van Deursen and Mossberger (2018) predicted in an earlier study that IoT would lessen the autonomy and control of its users. However, our findings suggest that autonomy and control are largely mediated by the IoT services and the materiality of IoT devices. The material means of IoT and operational skills activated can give people who start using IoT more autonomy and/or more control. In other words, less autonomy and control comply with our interdependency chain on Victims of Circumstance. However, in two other interdependency chains, Service Personalization and Ubiquitous Hobby, we found that cultural repertoires stimulate operational skills that can wager more control and autonomy for everyday activities.

Second, the absence of operational skills in one's repertoire is not enough to deter IoT use. With this regard, we (re)constructed skills specifically to address IoT and its social relations. With collaboration skills, individuals are able to obtain advanced services and support from third parties, which may have conflicting goals to maximize the service potential of IoT. This conflict becomes a wager of trust and privacy against effective IoT use. With choreographic skills, individuals maximize IoT use at preferable low costs. They have to adjust physical space, social space, and time available to increase efficient IoT use. Therefore, IoT can provide a substantial benefit to its users with composites of collaboration skills, choreographic skills, and operational skills.

Moreover, we have extended our empirical findings to cultural repertoires of action. On the one hand, collaboration skills tend to be compatible with a higher educational repertoire on the skills needed to reflect on digital information and digital communication. Higher educational repertoires provide the skills to navigate between service providers and decide which are more beneficial or reliable over others for effective IoT use. On the other hand, a lower educational repertoire seems more prone to value self-reliance, supported by operational skills. However, self-reliant IoT users also tend to feel a greater responsibility to make their IoT systems accessible and non-intrusive for other family members. Additionally, it is within the aims of this repertoire to increase IoT efficiency by actively seeking cheaper solutions to what is available on the general market.

### 5.2. Limitations and future research

Due to the qualitative nature of this study, we used education as a sensitizing concept rather than a structural disposition. Our participants were particularly selected to form a theoretical sample based on educational levels to present an alternative to higher educational repertoires. Readers should be careful not take remarks on education as conclusive but at theoretical considerations for future research. Additionally, socially constructed categories other than education can highlight different relational dynamics in IoT use. Therefore, we hope to inspire future research to be attentive to structural categories such as income and available monthly spending's, gender, age and the relations between categories. While we found no reason to suspect that IoT is exclusively gendered, attention to household responsibilities tends to shift from traditional gender roles as the devices become digitized. However, this research has been limited to setting up IoT systems and its maintenance, whereas gender differences might become more important during its actual use. Similarly, age is often important, while older users in the sample show that IoT is not exclusively for younger people. While consumer IoT use is at its earliest stage, research might be directed to the variety of tangible IoT outcomes and quantify the measures of these outcomes.

## Interview protocol

### Introduction statement

The research project is mainly focused in how the Internet of Things is being used, where, and with who. Whether it is for comfort, health, better control of energy consumption, just for fun, or any other experience. Our aim is to understand any difficulties that might surface when using the internet of things, which can be current and perhaps more situated in future use.

We do not expect you to be an expert in using the Internet of Things and you do not have to be a very active user. Your own experiences are most valuable to us!

Everything that happens during the visit is considered as sensitive research data. This means that nothing is shared with people who are not involved in this study, that your information is stored anonymously and secure. We document everything according to the privacy law of the EU.

Once the data has been processed, we might use some of your quotes to highlight and illustrate our findings to a larger audience in the form of a research article, but we prioritize your anonymity throughout the process. At any moment you can decide to stop participating. In such a case, we will delete your data. You can always come to me or my colleagues with questions, also after the study, about anything that might interest or concern you.

Before we start the interview, do you have any questions for me?

*General guidelines*

If examples or reasons are not given, ask for recent examples/ reasons why (not).

First time discussing a device or app, ask to show.

If the answer is not applicable, ask why not (important).

### **1. Starting to use the IoT and co-participation of use**

What are the IoT devices that you use?

Do you have your IoT devices connected to the internet?

Where do you have your IoT devices?

*Prompts:* - Any other smart devices?

- Any other devices you would want to be smart in the future?

Who uses IoT devices in this household?

*Prompts:* - Do you use the same IoT devices together?

- Who uses it the most?

Can you give an indication of how much you use your IoT devices?

*Prompts:* - More times a day, daily, weekly?

- When do you use it more?

Did you experience any difficulties while trying to purchase the IoT device?

*Prompts:* - Did you learn anything while trying to purchase an IoT device?

- Could you have prevented difficulties?
- Looked on the internet?

Do you think that you knew IoT well enough to make a purchasing decision?

*Prompts:* - What would do you different now?

Did you install your IoT devices by yourself?

*Prompts:* - Who took the lead during the installation?

- Asked anybody for help?
- Looked on the internet?
- Did you learn anything from it?

How did you decide on the placement of the device?

*Prompts:* - How long did it take to get familiar with the placement?

- Did you have the change the placement?

Did you decide on the settings of you IoT devices by yourself?

How did you decide what would be the best settings for you IoT devices?

*Prompts:* - When would you change those settings again?

- How long did it take to get familiar with the settings?
- Are you planning on changing settings in the future?

Do you ever share information generated by your IoT on the internet?

*Prompts:* - What kind of information?

- How do you share it?

Have you ever changed the settings to decide who you share information with?

Have you ever changed the settings to decide what information is being collected?

*Prompts:* - Is it (not) important?

- Would you change those settings again in the future?

Do you learn from each other about how IoT devices can be used?

Do you ever discuss newly discovered features?

*Prompts:* - When your navigating through apps?

- What IoT data means?

Does it change how you use your IoT devices?

*Prompts:* - Using it more?

- Better experiences when using?

Do you ever experience that you're less capable of dealing with IoT devices?

*Prompts:* - Would you like to do things better or smarter?

- Cannot find certain settings?
- Difficulty navigating through the app?
- Understand what the data means?

How do you respond when you experience such things?

*Prompts:* - Not use IoT device?

- Ask for help?
- Look on the internet?

Do you ever feel like you are losing control over your devices?

*Prompts:* - Devices make their own decisions?

- Less moments where you can decide?
- Not knowing what happens?

With what moments would/do you question your IoT use?

*Prompts:* - Concerns for IoT?

- Doubts over IoT use?
- Does it work as expected?
- Do you know what happens with IoT data?
- Ownership of IoT data?

## **2. Children (if applicable)**

Do your kids use IoT devices?

Do they give reasons to use the IoT?

Did you have to explain how to use it?

Do you learn from your children how to use the IoT?

*Prompts:* - Do you use it together?

- Do you ever ask your children to how to use the IoT?
- Do you ever ask how to use the IoT for you?
- Do they change settings?

Did your children influence purchasing IoT devices?

Do they influence where you placed your IoT devices?

*Prompts:* - Do they influence how you use the IoT?

- Would you change placement when they get older?

Do you think it is important that your children know how to use the IoT?

*Prompts:* - Do your children ever experience difficulties when using IoT devices?

- Can you help them with difficulties?

### 3. Friends and family as ‘warm’ experts

Do you have friends or family that use similar IoT devices?

*Prompts:* - Do they use other IoT devices?

Do you discuss the IoT with friends or family?

*Prompts:* - Experiences with hardware, software or apps?

- Advice on how to use the IoT?
- Share concerns?
- Does it change how you use your IoT?
- Use and user data?

Do you learn new things from friends or family when you discuss the IoT?

*Prompts:* - New features?

- Other uses?
- Other devices

Do feel like they ever learn from your experiences?

*Prompts:* - Do you influence how they use their IoT?

Are you able to estimate if friends or family are capable of using the IoT?

*Prompts:* - Who absolutely cannot use it?

- Who from your own age absolutely cannot use it?

Do you think that opinions of others are important for your IoT use?

*Prompts:* - Does it limit how much you use it?

- Limit the number of devices?
- When is it not important?

### 4. Organizations and manufacturers

Have you learned anything by organizations or manufacturers about IoT use?

*Prompts:* - What certain settings do?

- How to read and understand IoT data?
- How to help setting and achieving goals?
- How to secure your IoT network?

Wat has been made clear to you about IoT use when purchasing your devices by manufacturers?

*Prompts:* - Was that helpful?

- Did you miss anything?
- Are you satisfied with that?

Do you know what your user terms are?

*Prompts:* - What happens with the data?

- Is your privacy protected?
- What are their services?

Do you think that organizations and manufacturers should be more active in making the IoT accessible?

*Prompts:* - How could they help you more?

Did you approach organizations or manufacturers to learn more about using the IoT?

*Prompts:* - Would you ever do that?

- Do you have a need for that?

Did you approach organizations or manufacturers with problems or difficulties?

Prompts: - When would you do that?

- Did they help you?
- Would you do it again?

### Closing the Interview

Do you have any questions for me?

Is there anything else you would like to address?

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