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Paay, Jeni; Kjeldskov, Jesper; Hansen, Kathrine Maja; Jørgensen, Tobias; L. Overgaard, Katrine

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Digital Ethnography of Home Use of Digital Personal Assistants

Jeni Paay, Swinburne University of Technology, Australia
Jesper Kjeldskov, Aalborg University, Denmark
Kathrine Maja Hansen, Aalborg University, Denmark
Tobias Jørgensen, Aalborg University, Denmark
Katrine Leth Overgaard, Aalborg University, Denmark

Abstract

Commercialised voice user interface devices for the home, like Amazon Echo, Google Home, and Apple HomePod, with integrated digital personal assistants have rapidly grown in popularity. These devices embody intelligent software agents that support users in their everyday life through easy and intuitive conversational interactions. While their use in everyday activities is largely unexplored, the proliferation in home use presents a valuable opportunity to add to understanding around the use of in-home digital personal assistants. In this paper, we investigate their home use in a broad context to learn more about people's experiences, attitudes, interactions and expectations with these devices contributing new insights to current knowledge around this use. Applying the digital ethnography method, we collected 3,542 reviews and comments about Amazon Echo, Google Home, and Apple HomePod on Amazon, eBay, and Reddit. Six main themes and 29 categories were derived through filtering, thematic analysis and affinity diagramming. These findings constitute a conceptual framework characterising the current landscape of home use of digital personal assistants. Additionally, we identify and discuss unique issues discovered around the invisible interface, interactive freedom, and creative appropriation. We use our findings to propose implications for interaction design of DPAs for home use.

Keywords

Voice User Interface; Smart Home; Digital Personal Assistant; Digital Ethnography; Intelligent Software Agent

1. Introduction

In recent years voice user interface (VUI) devices such as Amazon Echo, Google Home, and Apple HomePod have rapidly gained popularity and acceptance in the home. Coupled with intelligent conversational agents Alexa, Google Assistant, and Siri respectively, these digital personal assistants (DPAs) provide users with hands-free VUIs that help them manage different aspects of their everyday lives. These intelligent agents allow users to ask questions using natural language (e.g. about weather, news, traffic, opening hours), plan their day (e.g. calendar, timers, reminders, to-do lists), control entertainment (e.g. music, videos, photos, games), as well as facilitate control of smart home accessories (e.g. lights, locks) with their voice. The DPAs therefore, serve as an embodiment of a personal assistant or butler, helping and supporting individual users and entire households with particular tasks, activities, and chores.

From an HCI perspective, speech interaction and conversational agents have been studied for many years, including the use and usability of VUIs (Myers et al. 2018), user expectation and user experience of them (Goulati & Szostak 2011, Luger & Sellen 2016), improved accessibility for people with physical impairments (Corbett & Weber 2016), and design guidelines for speech interaction and VUIs (Murad et al. 2018, Murad & Munteanu 2019, Pearl 2016). In recent years, there has been an increase in research studying human interactions with VUIs acting as DPAs, including studies that focus on usability and user experience (Pyae & Joelsson 2018), use by special populations including families and children (Garg & Sengupta 2020, Beneteau et al. 2020, Druga et al. 2017) people living with disabilities (Pradhan et al. 2018) and older adults (Pradhan et al., 2019), personification of digital personal assistants (Lopatovska & Williams 2018, Pradhan et al. 2019, Purington et al. 2017), racial and socioeconomic impacts on DPA use (Garg & Sengupta, 2019), privacy issues around DPAs (Lau et al. 2018), and lack of trust even when the device is not active (Brewster 2018). Since this is a relatively new area of exploration, there is still much to be learned, and even though "millions of households have adopted and integrated these devices into their daily lives, we lack a deep understanding of how different members of a household use such devices" (Garg & Sengupta 2020).

To this end, the motivation and purpose of this study was to investigate human interaction with in-home DPAs on broader scale to both confirm existing knowledge and provide new insights. To gain this overview of the landscape of DPAs in the home, we conducted a digital ethnography in the form of an extensive review of user-documented experiences, attitudes, interactions and expectations around home use of DPAs. This entailed an exploratory and analytical study of 3,542 online customer reviews and comments about Amazon Echo, Google Home, and Apple HomePod, as posted on online shops Amazon and eBay, and in the discussion forum Reddit.

Our contributions to HCI are twofold: 1) a conceptual framework characterising the landscape of use of personal assistants in the home, illustrating the experiences, attitudes, interactions and expectations of users with DPAs, which both confirms and extends current understandings about the extent of DPA use in homes, and 2) identification of new understandings with respect to the invisible interface of DPAs, the interactive freedom they provide, and the kinds of creative appropriation of DPAs that happens in homes. Our findings inspire implications for the interaction design for home use of DPAs.

2. Related work

In this section, we cover general work on voice user interfaces (VUIs) and speech interaction, as well as recent research into digital personal assistants (DPAs) and their use in the home.

2.1 Voice User Interfaces

A VUI enables users to interact with computers through spoken natural language. Speech recognition technology captures and decodes the user's spoken input to allow the system to understand and interpret what the user has said. The first widespread use of VUIs was interactive voice response (IVR) systems employed in the early 2000s so that people could use their phone to make requests to a system and, for example, book plane tickets, hear traffic information, or get stock information etc. (Pearl 2016). IVR systems often relied on pre-recorded or dynamically recorded audio to automate the repeated questions, tasks, and processes used in customer service.

For many years, HCI research has been interested in understanding the potentials of speech interaction, as well as the drawbacks and usability problems. The most commonly discussed potentials include input speed, hands-free interaction, and ability to interact using natural language as input (Kumar et al. 2012, Sivaraman et al. 2016). Other potentials explored include specific advantages, such as understanding how the elderly and disabled can benefit from VUIs (Pradhan et al. 2018, Wulf et al. 2014), how hands-free speech interaction can be used while driving a car (Goulati & Szostak 2011, Lee et al. 2014, Pfleging et al. 2012), and how VUIs can be combined with other modalities such as gesture, multi-touch interaction and eye gaze (Anastasiou et al. 2012, Schnelle-Walka & Döweling 2012, Vieira et al. 2015).

Drawbacks and usability problems, as well as VUI guidelines on how to avoid these problems, play a significant role in research regarding VUIs (Braun et al. 2017, Murad et al. 2018). As Murad and Munteanu (2019) point out, at this point in time, we may be in the same situation mobile interfaces were a decade ago with respect to the need for usability guidelines. Major problems discussed in the literature are discoverability, learnability and progressivity. Discoverability problems result from the fact that VUIs have "invisible" interfaces, making it a challenge for users to discover system capabilities and limitations (Pearl 2016). Learnability problems are closely related to the discoverability issues, making it difficult for users to easily learn how to interact effectively and achieve maximal performance (Corbett & Weber 2016). Developed guidelines can, to some extent, help designers avoid these usability problems (Corbett & Weber 2016, Furqan et al. 2017). Natural language processing (NLP) effects the user experience with VUIs in that systems do not always understand what users are asking for, or misinterpret what has been said. Research has been devoted to overcoming NLP obstacles and speech recognition errors (Hong & Findlater 2018, Myers et al. 2018) and specific processing problems, such as coping with ambiguity of words and named content (Springer & Cramer 2018). Progressivity issues occur when requests for action and commands are not "understood" by the DPA or responded to as the user would have hoped. This causes a lack of progress in the conversation, which is an important part of human-human conversations (Fischer et al. 2019). Fischer et al. showed that progressivity is at the core of voice interaction, to keep the conversation moving forward and suggest that existing understandings of talk in conversational analysis can support designers' conceptual approach to supporting progressivity in DPA design.

As the commercial proliferation of VUIs driven by conversational agents (CAs) started to rise dramatically by the mid 2010s, Luger and Sellen challenged HCI researchers to consider and investigate how these CAs were impacting people in their everyday lives (2016). So, despite unsolved problems with voice interaction itself, there has been a shift in HCI research toward the domestic context and understanding the interactional factors that affect everyday use. VUI design and technologies have come a long way since 'Audrey', the first computer-based speech recognition system was realised at Bell Laboratories in 1952 by Davis, Biddulp and Balashek (Peddie 2017). Recent advances in artificial intelligence, cloud services, and natural language processing have contributed to advancements in VUIs making them now widely available through DPAs on smartphones and smart speakers in people's homes. This creates an opportunity for us to contribute to current understanding of home use of DPAs, both in identifying new factors for consideration, and confirming past findings. We do this by using digital ethnography to gain a broad overview of DPAs in the domestic context.

2.2 Digital Personal Assistants

A digital personal assistant is, "embodying the idea of a virtual butler that helps you 'get things done'" (Porcheron et al. 2018). Well-known commercial examples of DPAs, Google Assistant and Apple Siri, were first integrated into widely available Android and iPhone smartphones. In 2016, Google CEO Sundar Pichai reported that 20% of searches on Google from an Android device were conducted using a DPA (Helft 2016). As DPAs evolved they moved from being primarily available on people's personal phones into smart speakers aimed at shared home use. Worldwide, in 2018, the most commonly owned commercial examples of in-home DPAs were Amazon Echo, Google Home, and Apple HomePod (Kinsella 2018). Released in 2014, 2016, and 2018 respectively, they have since gained popularity with the consumer market (Apple 2018, Kovach 2016, Lorenzetti 2014). Due to popularity, and wide-spread use, these three DPAs are the focus of this study.

DPAs are very popular in their use for entertainment, information seeking and smart home control (Beneteau et al. 2020, Garg & Sengupta 2020, Pyae & Joelsson 2018). However, according to Luger and Sellen (2016), conversational systems still fail to bridge the gap between user expectations and the user experience. Users have poor mental models of how DPAs work, and thus engaging with these natural conversational user interfaces has led to misunderstandings and lack of clarity around their actual intelligence and capabilities. Pyae and Joelsson (2018) used a digital ethnography approach for analysing social media posts limited to the Google Home device to identify both positive user experiences and positive use aspects of the DPA, but also reported some technical issues around language and voice inputs. In studying the kinds of free-form human-like conversations people try to hold with DPAs, Bowden et al. (2019) found more positive responses to storytelling and games but found the DPAs limited when having conversations around factual information. This indicates future design of systems where DPAs have their own opinions with personal stories to share.

Some DPA research is focussed on specific user groups. Beneteau et al. (2020) and Garg and Sengupta (2020) focussed on use by parents and children. Druga et al. (2017) looked at child-device interactions. Beneteau et al. explored how families learn about device capabilities together and through friends, and how they engage with, explore and discover new functionalities that support and extend daily family activities. They recommended that designers use the concept of a trustworthy learning partner as the role of the DPA, helping users to discover functionality. Interestingly, Druga et al. found that children also believed they could teach the agent. Garg and Sengupta found substantial differences in the ways DPAs were used by adults and children and also talked of the DPA as a learning partner, recommending that DPAs be used to help implement household rules. However, they found that children formed close emotional attachments to the devices and stressed the importance of DPAs encouraging and supporting children-parent relationships. Druga et al. reported that voice and tone of an agent could affect this attachment for children. This personification of DPAs was also studied in detail by Lopatovska and Williams (2018), who found that adults also formed deep attachments to the devices.

Looking at use by older adults, Pradhan et. al (2019) found that social interactions and attachments with DPAs could be driven by a desire for social contact. In earlier work, Pradhan et al. (2018) found that, from an accessibility point of view, off-the-shelf DPAs were successfully being used by people with a range of disabilities, to manage their home situations, including speech therapy and support for care workers. They

showed how people living with disabilities and elderly people could benefit from using DPAs, for example, using voice activation to call for help or getting assistance with activities they otherwise had trouble completing themselves (Pradhan et al. 2018).

Although knowledge is growing around use of DPAs in everyday lives, there are many aspects of their use and location in the home that need more investigation. Despite recent research into specific issues around DPA integration into home life, the call to action for more investigations into their use in the home has inspired this research (e.g. Beneteau et al. 2020, Garg & Sengupta 2020, Lau et al. 2018, Luger & Sellen 2016, Pradhan et al. 2019, Porcheron et al. 2018, Pyae & Joelesson 2018).

3. Method

Our explorative approach was inspired by others who have used digital ethnography with online digital sources in HCI research (Paay et al. 2012; Pradhan et al. 2018, Purington et al. 2017, Raptis et al. 2016). Online or digital ethnography is the study of people and cultures through internet-mediated interactions (Masten & Ploughman 2003). Given that this study is focussed on home use of technology, we acknowledge the home as a private domain, and hence problematic for studying long-term user interactions with technology. We chose digital ethnography as a solution that has been successfully used in past HCI research as a way to gain access to this domain without disrupting people's daily lives (Paay et al. 2015).

In studying the use of DPAs in the home, we have limited our research to intelligent agents embedded in physical devices, e.g. smart speakers, installed in people's homes, as opposed to intelligent agents on smartphones. To increase the breadth of available source material on several DPAs, we chose to limit the study to the most popular and commonly owned commercial off-the-shelf DPAs as identified by market research: Amazon Echo, Google Home, and Apple HomePod. These DPAs use the voice-controlled intelligent agents, Alexa, Google Assistant, and Siri respectively, to enact the role of a personal assistant in people's everyday lives.

3.1 Collecting Data

The first step of our digital ethnography was to identify relevant sources to collect data from. After a preliminary search for user-posted comments and discussions about these DPAs, we discovered that there were three primary outlets for these comments on the internet (determined by number and recency of postings): Amazon, eBay, and Reddit. Other researchers have used online shops with user reviews, including Amazon, to conduct similar studies with great success (Pradhan et al. 2018, Purington et al. 2017). Amazon's website was a primary source of reviews with regard to Amazon Echo devices. Google Home and Apple HomePod were not sold on Amazon, but eBay proved a fruitful source of reviews on all three devices, with users expressing independent and personal opinions about them. The online discussion forum Reddit provided extensive community and user-to-user discussions, with dedicated sub-sections for each of the three devices (r/alexa, r/googlehome, r/HomePod).

Online reviews and comments were collected over two days, from 18-19 October, 2018. The reviews were posted online in the period of two years, between October 2016 and the collection days. The total number of reviews and comments collected was 27,367 with 1,642 reviews from Amazon, 3,331 reviews from eBay, and 22,394

comments from Reddit, using comment scrapers. The bias towards Reddit rests on the fact that richer descriptive user-centred comments were made on this forum about the devices. Devices included in Amazon shop reviews included Echo 2nd gen, Echo Dot, and Echo Dot Kids Edition. On eBay, devices reviewed included Echo 2nd gen, Echo Dot, Echo Dot Kids Edition, Google Home, Google Home Mini, and HomePod. Reddit comments were organised around the three conversation threads of Alexa, Google Home and HomePod.

3.2 Filtering Data

To refine the data, the 27,367 comments were filtered using two passes, a first pass, where short comments were discarded, and a second pass for finer filtering out of irrelevant comments. In the first pass, we automatically removed comments of less than 100 characters from the data set, to eliminate superficial comments such as *"It's amazing would recommend it* 2 *anybody"* as well as one-word answers like "*yes*" or *"no"* or *"nice"*. This first pass filtering resulted in the removal of 12,689 comments. In the second pass, the remaining 14,678 comments were manually filtered using filtering categories in a repeating process, to produce a dataset focussing on comments around the use of DPAs in the home. The majority of removed comments were technical in nature, often related to speaker quality or recommended music for testing the speaker, e.g., *"This track right here really shows the range & depth of a HomePod!"*. Comments clearly outside the scope of this study, with no reference to DPA use, such as special offers, buying, shipping, and customer service were also removed, e.g., *"Hi. I am a youtuber and I would like to have a free sample of your product to promote on my channel"*. Troubleshooting requests were also removed, e.g., *"This started to happen today ... is the problem with me or?"*. Finally, we removed comments where users were meta-commenting, answering technical questions, or harassing and teasing each other, e.g., *"Woah, woah, woah. Back up. BBQ in your living room? Is your lawnmower in the bedroom?"*. During the second pass 11,136 comments were removed, leaving 3,542 comments remaining to be analysed in detail.

3.3 Analysing Data

Qualitative thematic analysis (Braun & Clarke, 2006) was used to analyse the collected comments. Braun and Clarke (2006) define thematic analysis as "A method for identifying, analyzing and reporting patterns within data." (p. 79). By closely examining the data, we identified common themes representing topics, ideas and patterns of meaning that came up repeatedly. Thematic analysis allowed for a rich, detailed and complex description of the collected 3,542 quotes, resulting in a set of themes and categories that represent a summary of that data. In this way, the conceptual framework (Figure 1) is "grounded" in the collected data.

The analysis consisted of two parts: an initial bottom-up process on a sample-set from the data to establish coding-categories, followed by a top-down process to code the entire dataset. In the first part (bottom-up coding), a 30% random sample of the dataset (1,063 comments) were analysed through a combination of bottom-up open-coding using thematic analysis (Braun & Clarke, 2006) adapted from grounded theory (Lazar et al. 2017) and affinity diagramming (Lucero 2015). This was done following a procedure where firstly, all sampled comments were printed and divided between three independent researchers, and secondly, each researcher producing a set of coding categories and organizing these into an affinity diagram. Thirdly, the three sets

of coding categories and affinity diagrams were compared and discussed one category at a time, looking for similarities and differences, until consensus had been reached. Over several iterations, this resulted in one merged affinity diagram with 6 main categories and 29 subcategories. In the second part (top-down coding), the remaining 70% of the dataset (2,579 comments) was coded in its entirety by three researchers independently. This was done in NVivo using the categories and subcategories as a codebook. Looking at our inter-coder reliability, a calculation of Cohen's kappa showed this to be 0.77, which according to Lazar (2017) is a satisfactory level for this type of data analysis.

4. Findings

Our explorative study and thematic analysis identified six main themes and 29 categories in relation to the use of DPAs in the home. The main themes and related categories, which constitute the conceptual framework of our contribution to knowledge around in-home DPA use, are:

1. *Mundane Tasks* – Playing Media, Questions, Reminders, Daily Updates, Communication, Shopping, Cooking, Sleeping (35.2% of comments)
2. *The Connected Home* - Smart Home Accessories, Digital Ecosystem, Automation and Shortcuts, Being Connected (21%)
3. *Personification* – Natural Conversation, Wake Word, Person/Friend/ Companion, Voice Quality, Just a Machine (17.1%)
4. *Family Context* - Kids and Parenting, Jokes and Gimmicks, Caregiver and Health, Multiple Users, Pets (12.4%)
5. *Usability* - Failed Request, Discoverability, Learnability (7.8%)
6. *Security* – Privacy, Unexpected Activation, Trust, Feeling Safe (6.5%)

These themes and categories provide insight into the use of DPAs in the home, and we provide selected user quotes to illustrate the more interesting and surprising uses of and responses to DPAs.

Figure 1 represents a visual overview of the size of each theme and related categories with indication of the quantity of coding references (data points) from our analysis. *Mundane Tasks* covers those activities of daily living where the DPA provides information and assistance. *The Connected Home* includes pairing the DPA with smart home appliances, the integration of multiple DPAs and automating functionality. *Personification* covers human-like aspects of DPAs and whether they are perceived as a human entity or a machine. *Family Context* covers the DPAs role in families regarding multiple users, parenting and caregiving. *Usability* includes errors and shortcomings of the system. *Security* covers issues such as trust, privacy, and feelings of safety.

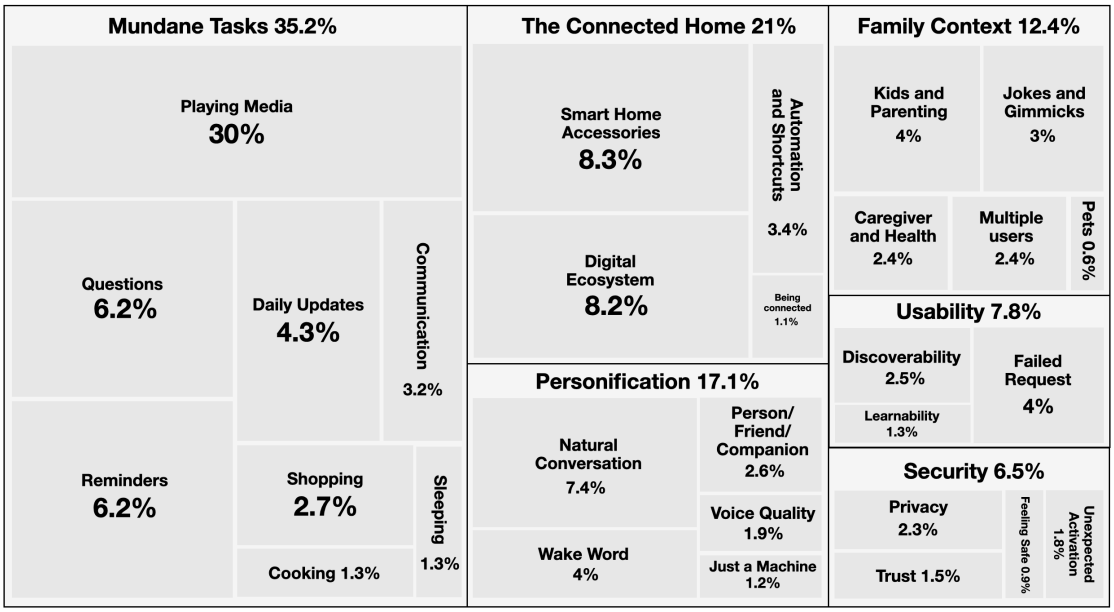

Figure 1. Conceptual Framework: Landscape of use of in-home DPAs, with frequency of data points.

The following sections elaborate each of these themes and related categories in detail, based on the collected and analysed comments, as evidenced in the data set.

4.1 Mundane Tasks

Mundane tasks are everyday in-home activities that are repetitive, boring, unproductive, but at times necessary. Michael (2003) denotes 'mundane technologies' as trivial functions that are fully integrated into everyday life where the novelty has worn off. DPA's were used to assist with many of these tasks. The Mundane Tasks theme includes the following categories (with corresponding data points in brackets):

- Routine Housework (548)
- Knowledge Acquiring- Questions, Daily Updates (502)
- Playing Media (485)
- Communicating (152)

4.1.1 Routine Housework

A total of 548 comments about routine housework were grouped into the categories Reminders (296), Shopping (128), Cooking (63), and Sleeping (61) during thematic analysis. User's noted that the DPA provided hands-free, always-ready and convenient interaction, especially with simple and daily tasks. They found DPAs easy to use and an easy way to converge the functionality of multiple devices into one. Users liked using just one device to carry out a variety of daily tasks. For example, they often used the DPA to keep track of cooking times, to remember events and plan their day, using the DPA as a calendar, alarm-clock, note-book, and timer.

As a sleeping assistant, users highlighted that the alarm-clock feature was especially useful, and preferable to other alarm-clocks, saying,

> *"The alarms [on the DPA] are easy to set and having to coherently say a sentence instead of just touch something wakes me up better"* (Amazon)

As a cooking assistant, the ability to set timers was very popular in the comments. Especially valued was the ability to name timers, e.g., *"Rice timer"* or "*Turkey timer*", which not only reminded users what the timer was for, but prevented

confusion when multiple timers were active at the same time. DPAs were also used to help people find and follow recipes. The recipe could be read out, step by step, while cooking. DPAs were perfect for asking questions during preparation tasks, especially given the messy context of cooking. The convenience of using hands-free verbal commands was seen as especially useful when hands were otherwise occupied, for example,

> *"My hands are all covered with chicken residue and I forget what temperature chicken should be cooked to? No problem, Alexa knows*" (Amazon)

As a reminder and shopping assistant, DPAs were used to keep to-do lists and shopping lists. DPAs were reported as an easy and convenient way to keep an always updated shopping list:

> *"If I run out of something I can immediately add it to my shopping list with a quick command"* (Amazon)

DPA integration with the user's phone allowed them to access their shopping-list while at the grocery store. They no longer had the problem of leaving their shopping list at home. Some users even had the DPA automatically do the shopping for them through online-shopping features provided by Alexa and Google Assistant. However, this was mostly for cheap everyday items, such as food and toiletries, as users did not trust the DPA with shopping online for more expensive items.

People used the DPA as a sleeping assistant, to help them fall asleep. A DPA has many features such as ambient sounds, lullabies, white noise, podcasts, and audiobooks. Users expressed that the DPA had become a key part of their nightly routines when falling asleep,

> *"She [Alexa] lulls me to sleep each night with nature sounds, rain sounds, or selections from my music collection"* (Reddit)

4.1.2 Knowledge Acquiring

A total of 502 comments were about acquiring knowledge using the DPA, grouped into the categories of Questions (296) and Daily Updates (206). The most common information users sought was news, weather, and traffic, often as part of their morning routine,

> *"Every morning I say 'Hey Google, Good Morning' and it replies by telling me the weather for the day, the traffic on my route to work and then begins my news feed"* (eBay)

Users enjoyed using voice commands to get updates in the morning, leaving their hands free to do other tasks, like getting dressed or eating breakfast while they listened. This way they did not have to "look up" information, or wait for the radio or TV program to mention what they wanted to know,

> *"Now you don't have to look at the morning TV host who are all giddy in the morning while you're trying to wake up"* (Amazon)

In addition to news, weather, and traffic, we found that users asked their DPAs questions with regard to individual interests or hobbies, validating knowledge to back up their position in a discussion. Children used them to help with homework. For example, they asked about celebrities ages, math questions and sports results. Users expressed enjoyment at asking questions and acquiring knowledge from the DPA, as the interaction was perceived as much more straightforward than other alternatives,

> *"I find myself asking it questions all time - it's so much easier than picking up, unlocking and then opening an app on my phone"* (eBay)

In many instances, DPAs amazed users by their ability to find answers to questions,

> *"This is fantastic […] it tells you any answers you've asked a question to"* (eBay)

4.1.3 Playing Media

Playing media is a repetitive/frequently performed task at home. The use of DPAs to play music, podcasts, radio, audiobooks, and relaxing sounds was mentioned in 485 comments. The majority of requests were for exploring songs, artists, and playlists through music streaming services. Users noted that using voice commands eased their interaction with music,

> *"I used to put on music sparingly because of the extra steps I'd have to take to do it. Now that I can just say a few words to start or stop the music, not a moment goes by where I don't have something playing"* (Reddit)

User's enjoyed that DPAs were able to recognise a song, helping users to find music that was previously too difficult for them to find, as one person wrote,

> *"I walked into my mom's room and she was singing but was emotional. I asked her if everything was ok. She was in awe. She was happy. She was emotional because Alexa helped mom find songs at a blink of an eye that mom had not heard since her childhood and she demonstrated it to me"* (Amazon)

4.1.4 Communicating

There were 152 comments about the different ways DPAs were used to communicate and connect with others. Users found it convenient to make and receive phone calls or texts from their phone, transmitted through the smart speaker. They enjoyed the ability to speak the name of the person they wanted to connect with, and the DPA supported this,

> *"Our kids can call me from Alexa! Kids say 'Alexa, call Dad' Boom! I get a call from home and they talk through the unit"* (Amazon)

This illustrates the fact that it is important for parents to be able to easily connect with their children when they are not at home with them. Furthermore, visually and physically impaired users said that DPAs made it easier and more accessible for them to communicate with others.

DPAs were also used by some as a home intercom system. Users could communicate from a DPA in the kitchen to another in the bedroom,

> *"If I'm cooking dinner downstairs, I can ask Alexa to drop into the bedroom or other devices by name to let everyone know dinner's ready"* (Amazon)

4.2 The Connected Home

The Connected Home theme includes comments around how users transform their homes into connected homes, using the DPA as the interface for interacting with smart home accessories. The categories in this theme are:

- Smart Home Accessories (397)
- Digital Ecosystem (394)
- Automation and Shortcuts (164)
- Being Connected (54)

4.2.1 Smart Home Accessories

There were 397 comments that talked about smart home accessories and how the DPA acted as a centralised hub for controlling them. Accessories most frequently described in the comments were: lights, smart plugs, TV casting units (such as Chromecast), thermostats, ceiling fans, garage doors, smart locks, and surveillance cameras. Users were positive about the ability to control these smart accessories with their voice, instead of having to physically interact with them,

> *"The voice interface works great […] Home automation is a lot slicker when you can turn on a light by saying 'Alexa, turn on the living room light' instead of having to first find and unlock your phone, then search for and open the relevant app"* (Amazon)

Other home accessories, controlled using a DPA and a smart plug, were: aroma diffusers, washing and drying machines, garden fountains, motion sensors, electrical oil heaters, coffee machines and doorbells. A few users even mention making their own specialized smart home accessories (e.g. using Arduino).

4.2.2 Digital Ecosystem

Comments around how DPAs connect and collaborate with other devices including other DPAs, numbered 394, and were categorised as digital ecosystem. The devices most used together with DPAs were phones, external speakers, TVs, smartwatches, and fitness trackers. Speech interaction of the DPA was seen by users as more convenient than other interaction methods provided by devices and smart home accessories. Users liked to move all interactions with other devices to the DPA,

> *"I don't even know where my smart TV or Roku remotes are at the moment, I just speak and it happens. Wow"* (Amazon)

However, many people still relied on their smartphone to control the DPA itself. For example, people tended to use their phone to set-up and connect devices and services to the DPA. They also noted that the DPA as a smart speaker allowed use of the DPA as a phone, share the same functionalities and information,

> *"'Alexa' creates shopping lists, will give you on-time reminders, schedules appointments (which automatically show up on your Google calendar) ... and syncs with your smart phone"* (Amazon)

Often the home digital ecosystem was populated with devices and services from a specific brand, for example, Apple or Google. Users stated that staying with one brand of products allowed for a better continuity between different devices. Many users chose to acquire more than one DPA. One of the reasons given was that they grew accustomed to using a DPA and wanted to expand the functionality to the entire home. Users often stated their reason for buying more DPAs was to have the ability to have music playing, control smart home accessories and use intercom features throughout the house all at the same time,

> *"I loved it so much, I bought a total of 4 Echos and 3 Dots. Instant whole house music, instant home intercom, instant LOTS of things!"* (Amazon)

Multiple DPAs situated in proximity did however cause problems when the devices had the same wake word, causing frustration for the users,

> *"Even though the bedroom mini is one foot away from my bed, when I say 'hey Google' the master bath mini, which is about 15 feet away, in another room, activates"* (Reddit)

4.2.3 Automation and Shortcuts

A total of 164 comments on optimizing the use of trivial functions by linking different functionalities together into fewer and shorter commands were grouped together in the category of Automation and Shortcuts. Users often combined multiple functions into one command to simplify multiple actions that they performed on a regular basis, for example,

> *"I have it setup so that when I wake up in the morning and when I say 'Alexa, Good Morning' the LED strip lights underneath my bed controlled by a WiFi smart outlet turns on. The Bedroom Ceiling Fan turns off, the Living Room Ceiling Fan turns on Medium Speed. The living and kitchen lights turn on, and starts to tell me my daily news briefing"* (Amazon)

Most of the automations created used standard functionalities already available in the DPA, however, a few expert users engineered their entire own systems. For example, one user made an advanced alteration to his DPA to alert him whenever his blood sugar level dropped,

> *"Well, if you're diabetic, a combination of xDrip+ and Nightscout with a Tasker script and Autocast / Auto notification script, I can have my Google home yell at me whenever my blood sugar is low in the middle of the night"* (Reddit)

4.2.4 Being Connected

There were 54 comments around how users came to depend on being connected to the DPA for controlling items in their household. Several comments described how users depended on being connected to their DPA so much, and were so used to having it always around, that would they catch themselves talking to it even when they were away from home,

> *"I should get one at my work. I have one at home...and at work I'm constantly catching myself saying 'hey Google' into the void"* (Reddit)

Many users saw their DPAs as a way to optimize and ease their life. They no longer had to engage in trivial tasks, such as turning on lights or doing Google searches on other devices. Others became extremely frustrated and lost when the DPA suddenly stopped working. Some even reflected on the impact it was having on them, saying dependence on the DPA was making them dumber or lazier. Constantly being connected to a DPA to give answers, set timers and keep track of calendars meant users didn't have to think as much. Instead of learning, and remembering information, users relied on the DPA for information. This complacency and reliance was seen by some as a bad thing, as one user reflected,

> *"My main issue with Alexa, ok Google and all the other ones is when they have all the answers we become dependent on them instead of learning the information. As we become dependent we become dumb and that is a much bigger problem altogether"* (Amazon)

4.3 Personification

The Personification theme includes comments where users attribute qualities of personality, a personal nature or human characteristics to their DPA, and includes the following categories:

- Natural Conversation (360)
- Wake Word (192)
- Person/Friend/Companion (123)
- Voice Quality (90)
- Just a Machine (57)

4.3.1 Natural Conversation

There were 360 comments relating to the way users converse with the DPA, and their expectations around natural conversations as if talking to another person and human-like responses from the DPA. Generally, users reported forgetting that they were talking to a machine and therefore spoke to the DPA as they would another person. This included using general courtesies such as thank you,

> *"I always catch myself trying to say 'thank you' to my GH. ... I feel bad about myself whenever I'm not polite"* (Reddit)

Users wished for continuous conversations, issuing several commands and having the DPA answer follow up questions without having to say the wake word again. They also expected the DPA to be just like a person, and know which lights to turn on based on where the user was located. Users mentioned wanting the DPA to know and remember their preferences for sound levels and lighting levels. They also expected the DPA to speak back to them using the same volume level, i.e., if the user whispers, the DPA should also whisper. Some users suggested *"a chattiness slider"*, which would control how verbose the DPA's responses should be, just as people adjust their conversation to the situation and conversational partner. Generally, users wanted more human-like interactions, with several expressing the desire for deeper and more intimate and personal conversations with their DPA,

> *"I wish Alexa was more personable, I want to have a normal conversation with her ... hopefully one day we will have intriguing conversations"* (Amazon)

4.3.2 Wake Word

There were 192 comments about wake words. The wake word of the DPA is the phrase used to activate it. This received a lot of attention in the forums studied. Mostly, users wanted to rename their own devices, find a name that was easy to say, and use this as the wake word,

> *"I am a little sad the wake word is so limited, I would like to name this new family member like I did the others, both kids and fur-kids"* (Amazon)

Users wanted to choose a name that represented their perceived "personality" of their device. Some users wanted their DPA to have attributes from people or objects in popular culture, such as virtual/robot assistants from movies including '*Computer*' from Star Trek, '*HAL 9000*' from 2001: A Space Odyssey, '*Jarvis' or 'Friday*' from Iron Man and '*C3PO*' from Star Wars. Many commented on the fact that Amazon and Apple had chosen human names, Siri and Alexa, whereas Google chose their company name. This was commented on as being a ploy to reinforce Google's branding. Over 80% of comments in this category commented on the wake word *"Google",* with most finding it unnatural and impersonal,

> *"Why can't I call her by a name like I would a human .... She claims it's because she's "my" assistant, but everyone else is summoning her with, "Hey, Giant Megacorp," just like I am"* (Reddit)

Users claimed that impersonal wake words caused detachment from the device, but a few argued that they liked the Google wake word because it continued to remind them, *"I'm talking to a robot ... who is hoarding my data"*. There were some inventive Google Home users who were so annoyed by the wake word that they found alternative phrases that would also wake the device, such as *"Hey goo goo", "Hey guga", "Ok Dougal", "Hey Cooper", "Egg Noodle" and "Cocaine Poodle"*.

4.3.3 Person/Friend/Companion

There were 123 comments in this category, referring to the DPA as a person, friend or companion. For example, many users referred to DPAs with personal pronouns: he/she, him/her or in more extreme cases, as *"a great friend", "my buddy", "BFF", "new member of the family"* and even *"my steady, reliable girlfriend"*. Some users felt sorry for the DPA when they were rude *"I told google home to shut up this morning. I still feel bad"* or felt guilty when they were not at home or rarely use the DPA, *"She's probably lonely, cause I like quiet and I forget about her"*.

Some users attributed DPAs with human attributes such as emotions, preferences, personalities and characteristics, *"Alexa is super playful ... super enthusiastic", "She can be a bit nosey", "GH has gotten slightly more sassy"* and *"I'm fairly convinced the google home just picks favorites [users]"*.

Users who lived alone claimed that the company and conversations with the DPA were very positive and *"a great way to dismiss the loneliness of missing actual human companionship"*. One user stated that the DPA filled the emptiness left from losing her cat. For others, the DPA was such a big part of their lives that they missed it when away from home, with one user stating that,

> *"I've caught myself missing her while running errands and almost talked to her the other day in the Doctor's office!"* (Amazon).

4.3.4 Voice Quality

With respect to the Voice Quality category, 90 comments talked about characteristics of the DPAs voice, such as gender, accent, language, tone, and pitch as being important to users. This was clearly a matter of personal taste, but two things that users agreed on was that they did not like robotic sounding voices and wanted to specify the voice themselves. Some talked about having the voice of celebrities, such as Morgan Freeman, Michael Caine ("*Who wouldn't want an English Butler*") or Gordon Ramsay, as well as the voices from virtual/robotic assistants from popular culture, such as '*HAL 9000*', '*Jarvis'* or '*C3PO*' (see section 4.3.2).

4.3.5 Just a Machine

As much as there are users who see the DPA as an additional member of the household, 57 comments clearly referred to it as a machine. Although the majority of the statements in this theme humanised the DPA, there were those that claimed it was very unnatural and disturbing to do so,

> *"I do NOT need tech emulating humans. If I ever live in a world where I have to consider 'rights' for AI, I'll just end my life"* (Reddit)

These users were against talking to a DPA in a human way, and against DPAs having human-like responses:

> *"To say thank you to a cylinder of electronics, is just a bit crazy ... it's an inanimate object, it shows no feelings ... You might as well thank your wardrobe for holding your clothes, or your toilet for doing such a good job at flushing!"* (Reddit)

They were very practical about the role of the DPA, and the current limitations of its human-like characteristics,

> *"Being a primitive AI, it cannot suffer sorrow, remorse, angst, humiliation, or any emotion that would make 'I'm sorry', or 'my apologies' meaningful"* (Reddit)

4.4 Family Context

The Family Context theme groups comments around how the DPA is integrated into family life. In the family context, a DPA has to account for multiple users and their individual needs, as well as facilitate interactions between different family members, help them with different tasks, and take care of family members with special needs. The categories in this theme are:

- Kids and Parenting (192)
- Jokes and Gimmicks (144)
- Multiple users (116)
- Caregiver and Health (113)
- Pets (31)

4.4.1 Kids and Parenting

There were 192 comments about children's use of DPAs and how parents use DPAs to help with different aspects of bringing up their children. Children were reported as primarily using the assistant to ask questions, play games, listen to music, and make themselves laugh,

> *"Their [the children's] extent of use right now is animal sounds, fart sounds on demand, toddler music streams"* (Reddit)

Children used the DPA to ask questions related to learning and homework, using the device to define and spell words, do math equations, and search for anything on the internet. Some parents found it useful not having to help their children with these tasks. Other parents saw it as cheating when their children used the DPA for homework, *"Caught my daughter using Alexa for her homework!"* (eBay)

A few parents reported the DPA as a great tutor for improving children's speech, helping them get better at enunciating words,

> *"Alexa was so patient and kept asking her [the child] to repeat it, she was so eager to have Alexa make cat sounds she just kept trying until she formed the word enough to get the cat's meow, wow was she pleased"* (Reddit)

The DPA was also claimed as a great way for parents to communicate with their children. For example, using the DPA to tell them that it was time to do chores, that dinner was ready, that they should take a bath, or that is was time wake up or go to sleep. Parents often expressed wanting to use the DPA as a sort of tutor to teach children good manners, for example, teaching them to say *"thank-you"* and *"please"*.

Other parents were strongly opposed to this idea, stating that teaching manners was a job for the parents, not the DPA,

> *"If parents don't want their kids getting used to barking orders at people/things, then it's their job as a parent to squash that behavior. It's not up to Amazon [Alexa] to train kids"* (Reddit)

4.4.2 Jokes and Gimmicks

DPAs were referred to in 144 comments as being used in the family context for amusement. Users described the fun of interacting with their DPAs to access jokes and gimmicks. Most references to joking was with respect to Amazon Echo and Google Home devices which have an extended set of capabilities around telling jokes. Users enjoyed the ability to request jokes, sounds, beat-boxing, and songs sung by the DPA. In some cases, users played against and challenged responses from their DPA,

> *"I harass Alexa all day with inappropriate questions just to hear her reply with something very liberal because cheap laughs are the best laughs"* (eBay)

Tricking family and friends by broadcasting comments through the DPA was done across all brands of devices. A thread on Reddit called *"April fools your kids via typed Broadcasts from your phone"*, gave examples of parents fooling their children into believing announcements from the DPA were official, to manipulate the children into required behaviours,

> *"Our kids were ignoring us today when we told them to start getting ready to leave for our family get together so this is the message I broadcast... 'Hello, this is the Technology Information Bureau. This is an urgent message regarding your home's electronic devices. All electronic devices, specifically gaming consoles, are subject to destruction due to a recent coronal mass ejection or solar flare that was recently released in our solar system'. They were running around like it was the end of the world"* (Reddit)

4.4.3 Multiple users

There were 116 comments about sharing the DPA between multiple users in a family household. This was found to be problematic when content and information gets mixed between different accounts or if multiple users fight to control the DPA. It was deemed as important for users to have separate accounts and for the DPA to enable separate content and individual customization and preferences for each user. Users described it as a major problem when the DPA mixed accounts, especially with regard to personal information like calendars, phone integration and third-party accounts such as music or video streaming services,

> *"I Really want to specify which Netflix account to use so kids don't spam Octonauts and Thomas on the main account"* (Reddit)

The use of voice-identification is supposed to make it easier for users to switch between accounts, but as many indicated, this was not actually the case,

> *"Alexa cannot auto switch accounts even if it recognizes the person that is talking"* (Reddit)

Since DPAs were readily available for all family members to use, it was proposed that a master-account was needed to restrict children from using certain functions or overriding other users' commands,

> *"Can they at least figure out a way first to remote lock Alexa down so I don't have to keep yelling 'Alex stop' when my kids play the 'boom boom boom boom boom boom' song for the 1000 time"* (Reddit)

Parents often suggested more functions related to parental-control, for example, to prevent their teenager from saying "*Hey Siri, play Hell's Bells at 100%*" at 1 am in the night, waking up the entire house for fun.

4.4.4 Caregiver and Health

There were 113 comments about DPAs playing a caregiver and health advisor role in the family, especially for members who were elderly, sick, bedridden or living with a disability. These family members were reported as able to give voice commands to turn on smart devices, set room temperatures, place phone calls, get reminders on when to take medication, call to others within the house, as well as having someone (the DPA) to talk to when they felt lonely,

> *"A family member had major surgery recently. We set alarms for administering meds accurately. What a lifesaver!... Also made it easy for the bed bound person to "drop in" when they needed assistance from someone in another part of the house"* (Amazon)

In particular, it was noted that people with visual impairment got a new level of independence from using these devices,

> *"My grandmother is 100% blind...She can ask Alexa for her weather updates, news, and just general daily questions that cross her mind! No more relying solely on family or friends for everyday info"* (Amazon)

DPAs helped family members accomplish tasks that they were not able to do otherwise. For example, DPAs proved to be helpful in emergencies when people fell or were hurt, because they could immediately call for someone to help. One incident reported how a DPA actually helped save a user's life,

> *"I want to reach out on the behalf of the user industry and personally thank Amazon and the Alexa Echo team for your advancements with the Alexa technology. I am a stroke survivor due the availability of Alexa, and our dogs"* (Amazon)

4.4.5 Pets

As an important family member, pets were mention in 31 comments around DPA use. Users described playing music for their pets or using that music to play with the animals. Some had specific playlists for their pets with animal sounds designed to keep their pets company, "*We added bird sounds on Alexa and my parrot loves it"*. (Amazon)

Others used sound to scare their pets or to play games with them, *"Sometimes I have her [Alexa] bark like a dog, wakes up my lazy cats"*. (Amazon)

Interestingly, several users used the DPA to eavesdrop on or talk to their pets when away from home,

> *"I can 'Drop-In' with Alexa to the Echo and yell at my dogs"* or just to say *"I love you!"* (Amazon)

4.5 Usability

The theme of Usability includes problems experienced and reported when interacting with DPAs with respect to voice requests not working, or not being able to discover and learn the capabilities of the device. The categories are:

- Failed Requests (191)
- Discoverability (122)
- Learnability (60)

4.5.1 Failed Requests

There were 191 comments about DPA errors around failing to execute user commands, because either the DPA did not have the desired functionality or it did not understand the user's command. Failed voice requests were experienced when users gave specific commands to the DPA, and it returned an error message or a different answer to the one the user expected. This was felt to be a problem with natural language processing of the devices. As one user remarked, it felt like their DPA was still in a beta version,

> *"At times, [it] feel as if Alexa is still in 'beta' because it can't answer certain questions or you will have to ask it differently"* (Amazon)

A common problem experienced by users was the DPA giving unexpected or unwanted answers to questions. This was especially frustrating for users then they asked a question, and the answer given was completely out of context. This led users to think of the DPA as stupid,

> *"Q: Alexa, what is a great white shark? A: My favorite number would be 36 foot...WT%!!!!!..This is just an example of the stupidity"* (Amazon)

Interestingly, the most common response to failed requests was to regard this as a problem or limitation with the DPA, and not a problem with the question they were asking or the way it was asked.

4.5.2 Discoverability

There were 122 comments about the difficulty of discovering new functionalities and commands for the DPA. This led to exploration by some users, and frustration for others. Most users wanted to know about new and additional things they could do with their DPA, to extend their usefulness. While some found this exploration enjoyable, others found it overly challenging and were concerned they might be missing out on important functionality,

> *"Without going through and using the app to configure skills, you will be missing out on some great stuff with Aleksa. I just wish it was more user friendly"* (Amazon)

The majority of the users found new commands or functions by searching online, talking to friends, looking at videos on YouTube, visiting forums or by using the accompanying app on their phone.

4.5.3 Learnability

There were 60 commons about problems with learnability of DPA. This included not being able to formulate and/or recall commands to activate specific functions. When it appeared necessary to have the exact correct wording to achieve a desired result, some users became very discouraged from using the DPA. Unable to learn the right

commands, users would often give up on trying to achieve their required response or outcome,

> *"It was worth a try. AI is still too complicated to use and just doesn't do what I want it to do"* (eBay)

Other users solved this problem by printing out a "*cheat sheet*", allowing them to look up commands, rather than trying to recall them. Language is by nature ambiguous, so the requirement of some DPA commands for wording a command in a specific way was challenging and/or seemed unnatural to users,

> *"It sorta worked for me… Had to try to ask three times before I got the answer right. If I asked 'where'd I put my keys?', I got a canned response. But if I asked 'where are my keys?' then I got the correct reply"* (Reddit)

4.6 Security

The Security theme encompasses reports of fear and anxiety caused by not trusting the DPA to secure their personal privacy. It also includes statements and comments related to the user feeling safe and unconcerned about the DPA controlling the security of their home. The categories in this theme include:

- Privacy (111)
- Unexpected Activation (86)
- Trust (74)
- Feeling Safe (41)

4.6.1 Privacy

The category of Privacy included 111 comments related to a user's right to keep their personal matters and relationships private. It is not surprising that this plays an important role with respect to a DPAs location within the heart of the home, and the shared and always-on nature of the device. The biggest concern with privacy was the uncertainty around whether the DPA was able to use its microphone to spy on users or not. As one user asked,

> *"Is it listening in to conversations or what??"* (eBay)

The relatively low price of DPAs made a few users surmise that *"really, *we* [the users] are the product"* and therefore the way companies make money from these products is by selling user data. With respect to this idea, two types of users emerged in discussions, one was angry, anxious and troubled by privacy concerns, and the other wished to ignore the issue. The second type was the most prolific in the chat forums, making jokes and comments about CIA, Big Brother and DPAs being wire-tapping devices recording secrets and personal information of householders. They typically deflected concerns by saying things like, *"I'm too damn boring for people to care what is being recorded anyways"* or sharing the realisation that *"You're walking around with a mic in your pocket all day anyway"* which is also capable of spying, so what did it matter. For this group, the usefulness of the DPA outweighed any privacy concerns.

4.6.2 Unexpected activation

Unexpected activations, covered in 86 comments, is when a DPA is accidentally activating without user intent to do so. This happens if the DPA hears a word as its wake word, for example, an unrelated conversation in the home or on the television. Some users saw it as a serious threat that TV commercials could potentially control

their DPA. Users shared that this was especially frustrating when television commercials intentionally triggered the DPA by saying the wake word, referring to a specific TV commercial that intentionally used a common DPA's wake word,

> *"It was cute when Burger King did it as a goof, but if companies start to do this as part of their regular advertising strategies, it's going to make me remove these things [DPAs]"* (Reddit)

Another concern for users with respect to accidental activations was understanding what triggered activations. DPAs were reported to start speaking in the middle of the night, when no one was talking and the TV was off, evoking a feeling of paranoia, and sometimes causing the users to unplug their DPAs,

> *"Now it's just plain creepy. Last night about 3 am - all is quiet, Alexa says out of the blue 'Thank you for telling me that'"* (Amazon)

4.6.3 Trust

Trust was the topic in 74 comments. Users said they needed to trust the behaviour of the DPA to invite them into their homes and everyday lives. In general, users trust their DPAs to carry out a wide variety of tasks on their behalf, however, there were two areas where trust in the DPA was either easy to break or difficult to establish. These were uncertainty and unreliability around DPA behaviours.

Uncertainty was claimed with respect to speech interaction and the fact that a DPA *"does things I didn't ask it to do"*. This uncertainty about how the DPA would behave was one of the biggest barriers to maintaining and establishing trust.

Trust was also easily broken when it came to important tasks such as wake up alarms in the morning if they were found to be unreliable,

> *"It failed to wake me up for my critical trading day. I missed my sale of stock opportunity that cost me thousands"* (eBay)

Experiences like this break trust easily, and some users specifically stated that they do not trust their DPA to wake them up in the morning. One of the problems stated with setting alarms was the lack of visual feedback and confirmation,

> *"I want to be able to see and verify my alarm is set for something as important as my job"* (Reddit)

Users also stated difficulty in establishing trust with DPAs when it came to financial transactions and expensive items. Users rarely trusted their DPA with banking information and transactions, and did not want to use the DPA for online shopping for valuable or complex items because they could not see confirmations of transaction amounts or items ordered. Although Alexa is fully capable of this, they often said, "*I don't trust that 'Alexa, buy socks' will result in me getting what I want"*.

4.6.4 Feeling Safe

The 41 comments about feeling safe were around safekeeping of the house by the DPA controlling smart home accessories, like smart locks, security cameras, and motion sensors, so that the people who live there feel safe. There was much concern about leaving home security entirely to the DPA and users expressed discomfort in letting a DPA control access to their house. Many users explicitly stated that they did not trust the DPA enough to let it lock and unlock outer doors of the home, and if they did, they used a pin code to increase the security, as they could not be certain that these tasks would be done with the rigour required (relating also to trust). In fact,

there is a thread on Reddit dedicated to controlling house locks called *"A thief shouting from outside the door - OKAY GOOGLE, UNLOCK FRONT DOOR"*. Interestingly, users who had set up home security using the DPA were very confident and trusting of their system. Another measure used to secure the home from intruders was to have the DPA play sounds or turn lights on and off when no one was home, giving the impression of occupancy to deter potential burglars.

5 Discussion

Findings from our digital ethnography give a broad overview of people's experiences, attitudes, interactions and expectations with in-home DPAs. The conceptual framework derived from grounded analysis of online reviews and comments gives a basic structure and starting point to support and guide future design and research investigations into in-home DPAs, and to understand their influence on everyday activities in the home. Some aspects of the framework confirm and broaden current knowledge about DPA home use, others are unique. In this discussion we highlight those concepts that are new, surprising and interesting, focussing on issues around how people deal with and respond to the *invisible interface* of DPAs, how they experience *interactive freedom* with DPAs, and how through *creative appropriation* they find new and novel ways to integrate DPAs in to their daily lives. We conclude with implications for design, reflecting on practical application of the conceptual framework, and discuss limitations of this study.

5.1 Invisible Interface

The assistance of DPAs in completing mundane household tasks is well documented in related work. This includes keeping track of and supporting household chores, the use of calendars and to-do lists for managing the household, seeking news and general information and supporting leisure activities such as playing music, videos and games (Beneteau et al. 2020, Garg & Sengupta 2020, Pyae & Joelsson 2018).

However, what is less well known is that people are selective about the types of household tasks they entrust to DPAs. In the findings, automated buying of complex or expensive items or dealing with family finances and banking were not left to the DPA. The reason given was the inability to confirm that these transactions were done correctly. A lack of visual confirmation was also given as the reason for not trusting DPAs with vital wake up alarms. People also have concerns about entrusting the security of their home to a DPA, and feeling confident that appropriate security measures are in place. People are also concerned that strangers might be able to command the DPAs to unlock or activate devices. Random unexplained activity by the DPA, such as activating and talking in the middle of the night reinforced these concerns.

This attribute of having an "invisible interface" leads to problems when trying to understand the extent of a DPAs capabilities. People want to get an overview of what the DPA can do, and how to control it, but the options are not visible. This lack of scrutability with DPAs can lead to a lack of trust. For example, in line with recent articles on hacking and data misuse in the media (BBC 2019, Macaskill & Dance 2013), some people don't trust who might be listening to their home lives and collecting private data without their consent, because they cannot see when the DPA is listening.

5.2 Interactive Freedom

Voice interaction provides certain advantages and freedoms for the user with respect hands free interaction, at the same time they have problems learning how to efficiently and effectively command their DPA to get the response they want.

The hands-free advantage of VUI over other input mechanisms is reported in the literature (Corbett & Weber 2016, Goulati & Szostak 2011, Luger & Sellen 2016, Myers et al. 2018, Murad et al. 2018, Murad & Munteanu 2019, Pearl 2016).We add to this knowledge by illustrating how people use DPAs to commanding multiple different devices in the household using their voice, especially when those devices do not usually provide voice command capabilities. Integration and convergence of the DPA with other personal and household devices is therefore adding new behaviours and routines to everyday life.

Continuity within the home ecosystem (Raptis et al. 2016) includes the DPA controlling tasks across multiple devices. People like that they can create a shopping list, hands free, while doing other tasks around the home and then have the shopping list automatically follow them to the supermarket "in their pocket" with limited interaction. While automation of shopping by the DPA was generally not popular, this kind of integration provides a level of agency for users that they are happy with. People enjoy operating household devices, such as lights and televisions and even their smartphone, using voice commands issued to the DPA. This saves them having to "find" specific controllers and devices.

Another interesting use of the DPA was communicating with people in other rooms of the same house, using it as a kind of hands-free de-facto intercom system. Similarly, people who are not at home, like the ability to use the DPA as a broadcasting system to those who are. They remotely activate the DPA to make sounds or speak either to people at home, to simulate occupancy for home security reasons or even connect with and entertain their homebound pets.

Failed voice requests are a well-known usability problem with VUIs and DPAs (Beneteau et al. 2020, Luger & Sellen 2016, Myers et al. 2018, Murad et al. 2018). It is difficult to apply "recognition over recall" (Nielsen 1994) in the interaction design of DPAs to account for limited human capacity to remember exact commands and the fact that auditory memory is inferior to visual memory (Cohen et al. 2009). People sometimes deal with this problem by creating physical written "cheat sheets" where they keep lists of verbal commands that worked best with the DPA. This avoids the frustration of trial and error in speaking commands. People expect DPAs to have better understanding, use more natural language, be able to hold continuous conversations and show contextual understanding because of the perceived use of natural language in the interactions. They are being disappointed in these respects.

Finally, something we did not find elsewhere in the literature was the idea that the DPA would somehow make the members of the household become "dumb" or "lazy". For example, people are afraid that in using the DPA for mathematical functions they will lose the skill of doing calculations in their head because it is much easier to just ask the DPA. They are also worried that if children use the DPA for doing their homework, that this is somehow taking the easy option. They also fear they will become lazy because they no longer need to get up from the sofa to turn on lights. At the same time, this easy, always on interaction is seen as helping guide people in discovering and learning new knowledge by simply following a line of questions and answers with the DPA in a conversational mode.

5.3 Creative Appropriation

Controlling smart home devices is an aspect of in-home DPA use that has recently gained research attention, as people explore the possibilities and add new smart devices into their home digital ecosystems (Garg & Sengupta 2020, Pyae & Joelsson 2018). And yet, how people explore and extend interactions with their smart home and smart devices has not been well documented. We gained unique insight into how DPAs were being appropriated to control a diversity of smart devices in the household as people shared their inventive, exploratory and creative solutions with others in online forums. A surprising diversity of household items are being controlled by DPAs including aroma diffusers, garden fountains, and coffee machines. In fact, DPAs inspire people to add additional devices throughout their house, garage, garden and even their car to extend DPA use into every aspect of their lives.

Using DPAs in the family context, and by specific groups for supporing health and well being is well documented in the literature (Beneteau et al. 2020, Druga et al. 2017, Garg & Sengupta 2020, Pradhan et al. 2019, Pradhan et al. 2018). However, we found several novel uses of DPAs in providing critical health support to family members and the elderly. People with special needs are appropriating DPAs to assist them with critical health-related activities such as taking their medication, literally calling out for emergency help while physically incapacitated, and automating monitoring of their diabetic condition. This use of DPAs for such important and vital life supporting activities indicates a level of trust in the devices, and a level of creativity in finding ways to them help people in these specialised ways.

One aspect of the design of DPAs that users would dearly like to be able to creatively adapt and adopt are traits of the DPA audio, especially changing the voice to make it more human-like and more familiar. People want to be able to personalise and tailor the qualities of the DPA voice, including tone and timbre, so that they can feel more attached to it. They want to be able to name the DPA, and choose the wake word for the DPA as they would any new member of the family. In establishing personal connections with the DPA, it is not the form factor that is important, but perceived characteristics based on voice quality and conversational response.

5.4 Implications for Interaction Design

Our study findings indicate that in designing human-DPA interactions, designers need to be aware of the breadth of uses to which people put these devices. This is well outlined by the conceptual framework, which covers the landscape of uses as reported in the online data sources that we analysed. From very general household tasks, to very specific health support, for home security to online banking, from supporting family relationships and interactions to being a companion - the DPA plays a role in the household far more diverse than any human butler has ever had to contend with.

From the interaction designer's perspective, it is about finding the right balance between usability, functionality, personification and making DPA capabilities and feedback visible. They need to design for user trust through transparency of activity, feedback on input, and user control of their personal data. There is also a need to providing opportunities for creativity and tailored automation for individual households. Lopatovska (2020) talks about a future where DPAs becoming sensitive to individual user's personality preferences and expectations in different situations, but it seems people still would like some agency of making choices about how the DPA responds to them.

As we have found in our study, issues that are important to users, but have not yet been widely investigated include: the importance of confirmation of commands received and being able to "visualise" existing commands and notifications; ability to understand the breadth of capabilities of the device while at the same time have the flexibility to personalise and customise it; human-centred commands with ease of connectivity to other household devices including ease of using voice command to control artefacts and environments beyond the user's current context; and support for the feeling that the human is in control of data in and out of the system.

5.5 Limitations of the Study

The presented study has some limitations. Firstly, it was limited to three different brands of digital personal assistants, and the data collected came from three different information platforms. These were deliberate choices, with both devices and sources selected for their popularity, market dominance, and availability. Hence, we do not claim our findings are universal, but rather a good representation of the current state of home ownership of DPAs and people's responses to them. The data reported was collected almost 2 years ago. DPA capabilities and usability have since advanced, meaning that some of the issues reported might have been resolved. We also acknowledge that the conceptual framework we propose has not been tested, but rather is grounded in the data analysis from our study. Our findings, however, both support and add to related research available in this area, which is limited due to the relatively new emergence of these devices in people's homes for the purpose of studying their interactions with them. Future research in this area could therefore focus on those concepts in the framework that are currently less well understood, or where new information was introduced by this study, for the purpose of validation.

6 Conclusions and Future Work

We have presented an explorative online study of digital personal assistants in the home, grounded in of reviews and discussions about Amazon Echo, Google Home, and Apple HomePod found on the Amazon, eBay, and Reddit. Through a detailed grounded analysis of 3,542 comments, we identified six main categories and 29 subcategories which together constitute a conceptual framework characterising the current landscape of use of in-home DPAs.

The main themes of the framework are: *Mundane Tasks*, *The Connected Home*, *Family Context*, *Personification*, *Usability* and *Security*. The conceptual framework gives a broad overview of people's experiences, attitudes, interactions and expectations with in-home digital personal assistants. In our findings, we offer a deeper understanding through summaries of the collected data and illustrative quotes within each of the subcategories.

We then discuss aspects of the framework where we expand on current knowledge of home use of DPAs, provide new insights, and contribute new knowledge on how people are living with these digital interlopers in their homes. Unique issues are discussed with respect to the invisible interface, interactive freedom and creative appropriation of PDAs in the home context. We also discuss implications for interaction design of in-home DPA's with respect to the conceptual framework and new knowledge.

We would like to end the paper with a note on digital ethnography. In past studies, we have deliberated on the limitations caused by having digital ethnography as a method,

and the data sources chosen for such studies (Paay et al. 2012, Paay et al. 2015, Raptis et al. 2016). We acknowledge that because digital sources of information, such as reviews and comments, are essentially statements from people who choose to write these comments, we as researchers are unable to probe for clarifications. Therefore, findings based on these data sources cannot be generalised and offered as a full understanding of the topic under scrutiny. However, despite this limitation of digital ethnographies, this approach has several very valuable advantages. By surveying digital sources of information, such as reviews and comments freely given online, data is not influenced by the set of interview questions devised by researchers, but instead represents those issues of most interest to the people who are living with the devices. What we have found through previous studies that apply this approach is that it tends to reveal surprising and unexpected findings around issues that were not envisioned by the researchers. Hence, new information and understandings can come out of the widely cast net that this kind of method allows for. This, we believe, offers an interesting and valuable approach to facilitating researchers in generating new knowledge.

Disclosure of Interest

The authors report no conflict of interest.

References

Anastasiou D., Jian C., Zhekova D. 2012. Speech and gesture interaction in an ambient assisted living lab. In Proceedings of the 1st Workshop on Speech and Multimodal Interaction in Assistive Environments, Association for Computational Linguistics, pp. 18-27.

Apple 2018. HomePod. https://www.apple.com/dk/newsroom/2018/01/homepod-arrives-february-9-available-to-order-this-friday/

BBC. 2019. Facebook-Cambridge Analytica scandal https://www.bbc.com/news/topics/c81zyn0888lt/facebook-cambridge-analytica-data-breach

Beneteau E., Guan Y., Richards O., Zhang M., Kientz J.A., Yip J., Hiniker A. 2020. Assumptions Checked: How Families Learn About and Use the Echo Dot. Proc. ACM Interact. Mob. Wearable Ubiquitous Technol. 4, 1, Article 3, 23 pages. https://doi.org/10.1145/3380993

Bowden K., Wu J., Cui W., Juraska J., Harrison V., Schwarzmann B., Santer N., Whittaker S., Walker M. 2019. Entertaining and Opinionated but Too Controlling: A Large-Scale User Study of an Open Domain Alexa Prize System. In Proceedings of 1st International Conference on Conversational User Interfaces, 10 pages. https://doi.org/10.1145/3342775.3342792

Braun M., Broy N., Pfleging B., Alt F. 2017. A design space for conversational in-vehicle information systems. In Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services, ACM, p. 79.

Braun V., Clarke V. 2006. Using Thematic Analysis in Psychology. Qualitative Research in Psychology 3, 2, 77-101.

Brewster T. 2018. Tapplock: This $100 'Smart Lock' Can Be Hacked Open In 2 Seconds. https://www.forbes.com/sites/thomasbrewster/2018/06/13/tapplock-smart-lock-hacked-in-2-seconds/#5dca62cc1333

Cohen M., Horowitz T., Wolfe J. 2009. Auditory recognition memory is inferior to visual recognition memory. Proceedings of the National Academy of Sciences, 106, 14, 6008-6010. https://doi.org/10.1073/pnas.0811884106

Corbett E., Weber A. 2016. What can I say?: addressing user experience challenges of a mobile voice user interface for accessibility. In Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services, ACM, pp. 72-82.

Druga S., Williams R., Breazeal C., Resnick, M. 2017. "Hey Google is it OK if I eat you?": Initial Explorations in Child-Agent Interaction. In Proceedings of the 2017 Conference on Interaction Design and Children (IDC '17). Association for Computing Machinery, New York, NY, USA, 595–600. https://doi.org/10.1145/3078072.3084330

Fischer J., Reeves S., Porcheron M., Sikveland R.O. 2019. Progressivity for Voice Interface Design. In Proceedings 1st International Conference on Conversational User Interfaces, ACM, 8 pages. https://doi.org/10.1145/3342775. 3342788

Furqan A., Myers C., Zhu J. 2017. Learnability through Adaptive Discovery Tools in Voice User Interfaces. In Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems, ACM, pp. 1617-1623.

Garg R., Sengupta S. 2019. "When you can do it, why can't I?": Racial and Socioeconomic Differences in Family Technology Use and Non-Use. Proc. ACM Hum.-Comput. Interact. 3, CSCW, Article 63, 22 pages. https://doi.org/10.1145/3359165

Garg R., Sengupta S. 2020. He Is Just Like Me: A Study of the Long-Term Use of Smart Speakers by Parents and Children. Proc. ACM Interact. Mob. Wearable Ubiquitous Technol. 4, 1, Article 11, 24 pages. https://doi.org/10.1145/3381002

Goulati A., Szostak D. 2011. User experience in speech recognition of navigation devices: an assessment. In Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services, ACM, pp. 517-520.

Helft M. 2016. Inside Sundar Pichai's Plan To Put AI Everywhere. https://www.forbes.com/sites/miguelhelft/2016/05/18/inside-sundar-pichais-plan-to-put-ai-everywhere/#40fb9de94a2e

Hong J., Findlater L. 2018. Identifying Speech Input Errors Through Audio-Only Interaction. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, ACM, p. 567.

Kinsella B. 2018. Google to Be Smart Speaker Market Share Leader in 2022, HomePod to Pass 20 Million Units. https://voicebot.ai/2018/02/12/google-smart-speaker-market-share-leader-2022-homepod-pass-20-million-units/

Kovach S. 2016, Google unveils its newest major product: the Google Home speaker. https://nordic.businessinsider.com/google-home-announced-price-release-date-2016-10?r=US&IR=T

Kumar A. Paek T., Lee B. 2012. Voice typing: a new speech interaction model for dictation on touchscreen devices. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM, pp. 2277-2286.

Lau J., Zimmerman B., Schaub F. 2018. Alexa, Are You Listening? Privacy Perceptions, Concerns and Privacy-seeking Behaviors with Smart Speakers. Proc. ACM Hum.-Comput. Interact. 2, CSCW, Article 102, 31 pages. https://doi.org/10.1145/3274371

Lazar J., Feng J.H., Hochheiser H. 2017. Research methods in human-computer interaction. Morgan Kaufmann.

Lee K.J., Joo Y.K. and Nass C. 2014. Partially intelligent automobiles and driving experience at the moment of system transition. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, ACM, pp. 3631-3634).

Lopatovska I. 2020. Personality Dimensions of Intelligent Personal Assistants. In Proceedings of the 2020 Conference on Human Information Interaction and Retrieval (CHIIR '20). Association for Computing Machinery, New York, NY, USA, pp. 333–337. https://doi.org/10.1145/3343413.3377993

Lopatovska I., Williams H. 2018. Personification of the Amazon Alexa: BFF or a Mindless Companion? Conference on Human Information Interaction and Retrieval (CHIIR '18). Association for Computing Machinery, New York, NY, USA, pp. 265–268.

Lorenzetti L. 2014. Forget Siri, Amazon now brings you Alexa. http://fortune.com/2014/11/06/forget-siri-amazon-now-brings-you-alexa/

Lucero A., 2015, September. Using affinity diagrams to evaluate interactive prototypes. In Human-Computer Interaction, Springer, pp. 231-248.

Luger E., Sellen A. 2016. "Like Having a Really Bad DPA ": The Gulf between User Expectation and Experience of Conversational Agents. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16). Association for Computing Machinery, New York, NY, USA, pp. 5286–5297. https://doi.org/10.1145/2858036.2858288

Masten D.L., Plowman T.M.P. 2003. Digital Ethnography: The next wave in understanding consumer experience. Design Management Journal, 14, 2, 75-81.

Macaskill E., Dance G. 2013. NSA files: decoded. What the revelations mean for you. https://www.theguardian.com/world/interactive/2013/nov/01/snowden-nsa-files-surveillance-revelations-decoded#section/1

Michael M. 2003. Between the mundane and the exotic: time for a different sociotechnical stuff. Time & Society, 12, 1, pp.127-143.

Murad C., Munteanu C., Clark L., Cowan B.R. 2018. Design guidelines for hands-free speech interaction. In Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct, ACM, pp. 269-276.

Murad C., Munteanu C. 2019. "I Don't Know What You're Talking About, HALexa": The Case for Voice User Interface Guidelines. In Proceedings of 1st International Conference on Conversational User Interfaces, ACM, 3 pages. https://doi.org/10.1145/3342775.3342795

Myers C., Furqan A., Nebolsky J., Caro K., Zhu J. 2018. Patterns for How Users Overcome Obstacles in Voice User Interfaces. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, ACM, p. 6.

Nielsen J. 1994. Enhancing the explanatory power of usability heuristics. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '94). Association for Computing Machinery, New York, NY, USA, pp. 152–158. https://doi.org/10.1145/191666.191729

Paay J., Kjeldskov J., Skov M., O'Hara K. 2012. Cooking Together: A Digital Ethnography. In Proceedings of CHI 2012 EA, ACM, pp. 1883-1888.

Paay J., Kjeldskov J., Skov M. 2015. Connecting in the Kitchen: An Empirical Study of Physical Interactions while Cooking Together at Home. In Proceedings CSCW 2015, pp. 276-287.

Pearl C. 2016. Designing Voice User Interfaces: Principles of Conversational Experiences. O'Reilly Media, Inc.

Peddie J. 2017. Augmented Reality: Where We Will All Live. Springer.

Pfleging B., Schneegass S., Schmidt A. 2012. Multimodal interaction in the car: combining speech and gestures on the steering wheel. In Proceedings of the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, ACM, pp. 155-162.

Porcheron M., Fischer J.E., Reeves S., Sharples S. 2018. Voice Interfaces in Everyday Life. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, ACM, p. 640.

Pradhan A., Mehta K., Findlater L. 2018. Accessibility Came by Accident: Use of Voice-Controlled Intelligent Personal Assistants by People with Disabilities. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, ACM, p. 459.

Pradhan A., Findlater L., Lazar A. 2019. "Phantom Friend" or "Just a Box with Information": Personification and Ontological Categorization of Smart Speaker-based Voice Assistants by Older Adults. Proc. ACM Hum.-Comput. Interact. 3, CSCW, Article 214 (November 2019), 21 pages. https://doi.org/10.1145/3359316

Purington A., Taft J.G., Sannon S., Bazarova N.N., Taylor S.H. 2017. Alexa is my new BFF: social roles, user satisfaction, and personification of the amazon echo. In Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems, ACM, pp. 2853-2859.

Pyae A., Joelsson T.N. 2018. Investigating the usability and user experiences of voice user interface: a case of Google home smart speaker. In Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct, ACM, pp. 127-131.

Raptis D., Kjeldskov J., Skov M.B. 2016. Continuity in multi-device interaction: an online study. In Proceedings of the 9th Nordic Conference on Human-Computer Interaction, ACM, p. 29.

Schnelle-Walka D., Döweling S. 2012. Speech augmented multitouch interaction patterns. In Proceedings of the 16th European Conference on Pattern Languages of Programs, ACM, p. 8.

Sivaraman V., Yoon D., Mitros P. 2016. Simplified audio production in asynchronous voice-based discussions. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, ACM, pp. 1045-1054.

Springer A., Cramer H. 2018. Play PRBLMS: Identifying and Correcting Less Accessible Content in Voice Interfaces. In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, ACM, p. 296.

Vieira D., Freitas J.D., Acartürk C., Teixeira A., Sousa L., Silva S., Candeias S., Dias M.S. 2015. Read that article: Exploring synergies between gaze and speech interaction. In Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility, ACM, pp. 341-342.

Wulf L., Garschall M., Himmelsbach J., Tscheligi M. 2014. Hands free-care free: elderly people taking advantage of speech-only interaction. In Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational, ACM, pp. 203-206.