“Hey Alexa, What’s Up?”: Studies of In-Home Conversational Agent Usage

Alex Sciuto, Arnita Saini, Jodi Forlizzi, Jason I. Hong
Carnegie Mellon University
Pittsburgh, PA, USA
{forlizzi, jasonh}@cs.cmu.edu

ABSTRACT
In-home, place-based, conversational agents have exploded in popularity over the past three years. In particular, Amazon’s conversational agent, Alexa, now dominates the market and is in millions of homes. This paper presents two complementary studies investigating the experience of households living with a conversational agent over an extended period of time. First, we gathered the history logs of 75 Alexa participants and quantitatively analyzed over 278,000 commands. Second, we performed seven in-home, contextual interviews of Alexa owners focusing on how their household interacts with Alexa. Our findings give the first glimpse of how households integrate Alexa into their lives. We found interesting behaviors around purchasing and acclimating to Alexa, in the number and physical placement of devices, and in daily use patterns. Participants also uniformly described interactions between children and Alexa. We conclude with suggestions for future improvement for intelligent conversational agents.

Author Keywords
Conversational user interfaces, Alexa, family

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous

INTRODUCTION
In 2017, it was estimated approximately 35.6 million people will interact with a “voice-enabled speaker” at least once per month. A conversational user interface (CUI) is a system that relies on chat, supported by artificial intelligence, to have verbal interactions with end users. While several companies have introduced CUIs, Amazon controls around 70% of the market, with between 7 and 11 million people owning at least one Alexa device. Many feel that Alexa and related devices have the potential to become an important part of many households [14,21].

DIS 2018, June 9–13, 2018, Hong Kong.

ttps://doi.org/10.1145/3196709.3196772.

Researchers have for decades studied how to build, deploy, and interact with a ubiquitous smart home [2,10,13,16,17]. Now that millions of people are able to purchase and set up an intelligent, conversational agent for a low cost, it is important to understand how researchers’ theories and intuitions match against the reality of living with these imperfect devices. The HCI community is forced to play catch-up in understanding how people actually integrate these place-based, conversational agents—best exemplified by Alexa—into their lives. Resulting knowledge will give researchers new avenues of research and interaction designers new insights into improving their systems.

This paper explores the research question of how households incorporate conversational agents into their lives. We first remotely gathered and analyzed the logs of 75 Alexa users, for a total of 278,654 voice commands. Participants also answered survey questions related to their household and use of Alexa. We then interviewed seven families who have owned an Alexa device for at least six months. They introduced their devices to the researchers and answered open-ended questions about how they use the devices. This mix of quantitative and qualitative methods allowed us to understand Alexa usage from a richer range of perspectives, helping us better understand what people do with Alexa and why.

Our contributions are as follows. We provide a rich description of people’s experiences in orienting to the technology and gradually integrating it into daily life. We draw out four main themes in this process: 1) the relationship between Alexa and the various rooms devices reside in; 2) the daily routines that incorporate Alexa and which Alexa supports; 3) acclimating to Alexa and expanding the ecosystem; and 4) limitations in human-system interaction (particularly for children). We thus provide knowledge about the process of incorporating home-based conversational agents into people’s lives. Additionally, we provide information about the limitations and shortcomings of the technology as it is designed today, and suggestions for how CUIs can be better designed in the future.

In the next section, we describe past work in CUIs, as well as the Amazon Alexa series of products. We review related work and the methodology for our two studies. We present findings from our data, design recommendations, and suggestions for future work.

RELATED WORK

Amazon Alexa Ecosystem

Amazon's Alexa devices were some of the first AI-powered CUIs to reach the consumer market. In November 2014, Amazon concurrently introduced its Echo home speaker and the Alexa conversational agent that powered it. This system had the ability to stream audio over Bluetooth, request radio stations, play music, make lists, ask about the weather and news, and order products from Amazon.com [14,21]. It can also answer rudimentary questions, though as one reviewer noted, "If Alexa were a human assistant, you'd fire her, if not have her committed."

Conversational agents may perform with fewer errors if they are part of a data and device ecosystem. For example, Amazon has steadily increased the number of devices that feature Alexa, including smart speakers (Echo, Dot, and the battery-powered Tap), a variant with a camera built in for fashion (Echo Look), a kitchen kiosk with a visual display (Echo Show), a magnetic bar-code scanner for the home refrigerator (Dash Wand), smart televisions, and a smart phone app. Amazon has released versions of Alexa for other hardware developers to use in their devices, and introduced third-party "skills" that allow users to customize particular tasks [5].

Amazon is currently leading the market for conversational agents. As of May 2017, it is estimated that the Alexa ecosystem controls 70.6% of "voice-enabled speakers," and that 35.6 million people in the United States will use a "voice-enabled speaker" at least once per month [28]. However, it is worth noting that there are other competing products. For example, Google Home devices leverage customer actions on Google; and Samsung's Bixby leverages customer actions with its ecosystem of smart products.

Conversational Agents

While working at Bell Labs in the 1930s, Homer Dudley was the first researcher to develop an electronic machine that produced human speech with his Vocoder system [12]. Ever since, researchers have attempted to produce systems that can both speak and understand human speech. These conversational user interfaces and conversational agents have numerous technical challenges including correctly parsing input audio into speech, parsing speech for meaning, applying logic, producing a response, and producing the correct synthetic voice. Many researchers have studied and continue to study these questions [26].

Conversational agents present special challenges compared to screen-based interfaces. Some research has articulated the shortcomings of conversational UIs, noting that since they are ephemeral, they are not optimal for traversing certain bodies of information, such as navigation with long lists [34]. Other research on conversational agents in the lab and in the real world showed that these agents need to display both interactional and propositional aspects of conversation, and must support both task-oriented and social dialogue [7]. These studies also revealed that human-like communication strategies were critical, because they helped people build social attributions with the agents, resulting in more trust and more frequent system use [6, 22].

Chatbots that use natural language processing to provide appropriate human responses in the context of a dialogue have been shown to influence the behavior of the user [4]. Therefore, they must be designed with particular strategies in mind [1,15]. More research is needed on chatbots and CUIs to develop approaches that work across a number of contexts and situations.

Ubiquitous Computing in the Home

HCI has a long history investigating ubiquitous computing in the home. Much of this work has involved conversational features that are reflected in the Amazon Alexa. In 2001, Nagel et al. proposed a system they called the "Family Intercom" that aimed to combine light-weight communication with environmental and social context for the home [23]. Oleksik et al. expanded the audio palette by suggesting "sonic interventions" for the home that could communicate social and environmental information [25].

Ubiquitous computing has also explored place-based, conversational agents outside the home. Cassell et al.'s Media Lab autonomous conversational kiosk is an early example. They created an agent located in the lobby of a college academic building that gave directions to visitors [6]. Other work has been located in museums [18] and in elementary schools [30]

Through constructing these systems, HCI researchers have developed a set of pain points regarding the successful commercial implementation of ubiquitous computing. These pain points are all seen in various degrees in the commercially available Alexa. Meyer and Rakotonirainy summarized the main challenges for a successful intelligent home as: home installation, system management, novel applications, user experience, and privacy [22].

How people settle into routine uses of technology in the home is an important question that a line of research has addressed. Early research explored how computing can be used in the home and how it can support domestic routines and key moments for communication, including activity centers and places where information is routinely displayed [8]. Chetty et al. [7] built on this work to understand how networked technologies impact the infrastructure of the home, reporting four themes that revealed confusion and extra responsibility in managing technology in the home. The CHI community has long come to realize that these user experience issues, exacerbated by the smart home's decentralized nature and hidden infrastructure, will determine the success or

failure of smart homes [3]. The CHI community has also focused on how use of technology at home changes over time, noting that designing to support daily rituals creates meaning in one's life [19]. As research in this area matures, more HCI research and design focuses on how to be sensitive to the needs of users and what an appropriate relationship between users and technology might be [10,24].

Empirical Work About Amazon Alexa

Amazon's Alexa ecosystem is the first commercially successful home ecosystem centered on a conversational agent. While there has been some early research into Alexa since it was launched three years ago, there is much more to do. Lopez et al. included Alexa in their comparison of popular conversational agents [20], which included Alexa, Google Assistant, Microsoft Cortana, and Apple Siri. They assessed naturality and correctness dimensions. No agent was clearly superior to any other. Druga et al. brought children, aged 3 to 10, into the lab to interact with text-based and voice-based agents, including Alexa. They found significant differences between how children interpreted the intelligence of agents when the agent was able to speak [11]. Finally, Purington et al. analyzed Alexa reviews from Amazon.com and found that owners personified Alexa, and that personification indicated greater user satisfaction [31]. Reviewers with multiple household members had greater levels of personification. We were unable to find any research that analyzed the logs produced by Alexa or performed in-home interviews to understand how households actually use the devices.

STUDY METHODOLOGY

To gain multiple perspectives on how households use conversational agents, we engaged in a complementary methods study comprised of one quantitative data logging study and one in-home contextual interview study. Here, we describe the methodology of each.

Conversational Device Log Quantitative Study

In July 2017, we conducted an online study to gather the history logs of Amazon Alexa users. We advertised on Amazon Alexa enthusiast forums, including Reddit forums aimed at Alexa, conversational agents, and home automation. We also posted on the Amazon Echo Users Forum website EchoTalk.org. After running the study for one month, we received 271 requests to participate, with 80 completing the entire study. We excluded 5 participants who submitted multiple identical sets of logs. Participants were compensated $15. Due to our advertising choices and participant self-selection, our participant pool likely skews towards enthusiasts, early-adopters, and "power users."

Participants downloaded and installed a Chrome browser extension that we created. This activated when they went to their Alexa history page and downloaded their logs. Each command included a transcript of the command, generated by Amazon. Commands also included a timestamp and an associated device ID. See Table 1 for a list of the thirty most common commands in the dataset.

We gave our participants a chance to exclude any logs they felt were too sensitive to share. Our Chrome browser extension let participants see what commands would be uploaded and select which ones should be removed before sharing with our team. The majority of participants chose not to exclude any commands (min: 0, max: 1,546, 25%: 0, 75%: 0, median: 0, average: 25.3). Finally, they answered a survey about their households, the conversational agents they own, and the kinds of behaviors they have engaged in.

Our participants skewed towards young people and males, and most participants appeared to live in nuclear families. 72% identified as male. Ages ranged from 18 to 59 with a median age of 32 and a mean age of 33.5. The household composition indicated that participants lived with multiple related people. 58% of respondents said they were either married or in long-term relationships. The most common familial relationships were "wife," "son," "husband," and "daughter." Only three participants listed having a non-related "roommate."

From the 75 participants, we gathered a total of 376,687 raw commands. 98,033 of those commands (26.0%) were wakeword commands ("Alexa" or "Echo") that trailed another command by less than four seconds.

Command	Count	Command	Count	Command	Count
alexa stop	12,811	alexa next	1,184	alexa what's the temperature	676
alexa	8,849	amazon	1,108	alexa volume down	660
stop	7,720	good morning	1,071	alexa play	645
alexa what time is it	2,190	hey alexa	917	alexa turn off kitchen	640
no	1,768	what's the weather	913	alexa skip	623
alexa pause	1,572	alexa good morning	865	alexa tell me a joke	617
what time is it	1,517	alexa resume	853	pause	594
yes	1,478	play	811	alexa turn on my light	591
alexa what's the weather	1,427	next	787	tell me a joke	575
Unknown	1,425	alexa volume up	776	play n. p. r.	555

Table 1 – 30 most popular Alexa commands from our participants' logs (N=75 with 278,654 voice commands).

Category	Keywords	Sample Commands	Count	
music	play, pause, song, skip, etc.	"play caskey on iheartradio" "alexa play jesus christ work Walmart" "alexa resume"	69,619	25.0%
other	—	"alexa start" "launch the bible app" "alexa turn that off"	56,446	20.3%
smarthome	office, kitchen, light, upstairs, etc.	"alexa turn the bedroom light off" "alexa turn on kitchen sink" "floor colors lights off "	40,870	14.7%
text not available	—	*Amazon was unable to transcribe due to misfire or low audio quality*	27,069	9.7%
weather	temperature, outlook, rain, etc.	"weather update" "what's the weather for tomorrow" "what's the weather in carlisle pennsylvania today"	12,731	4.6%
question	what's, where, why, where's	"alexa what's the difference between kosher salt and regular salt" "what is my drive to work look like"	10,409	3.7%
timer	timer	"set a timer for twenty minutes"	10,128	3.6%
wakeword	alexa, echo	"alexa" "echo"	9,715	3.5%
lists	shopping, list, add	"alexa add ritz crackers to the shopping list" "add girls shampoo to the grocery list"	7,714	2.8%
volume change	volume	"set the volume to five" "turn down the volume"	7,555	2.7%
personality	are you, is your, good morning, etc.	"good morning" "alexa good night" "alexa thank you" "simon says hi thank you so much"	7,366	2.6%
time	time	"what time is it"	6,219	2.2%
alarm	alarm	"alarm in fifteen minutes" "alexa set an alarm at nine thirty five a.m."	4,265	1.5%
news	news, briefing, flash, update	"stop the news" "ask cnbc if the latest news" "alexa daily briefing"	3,058	1.1%
joke	joke	"tell me a trump joke" "tell a joke" "tell me another joke"	2,819	1.0%
connectivity	bluetooth, pair, connect, sync	"alexa connect to phone" "connect to yamaha" "alexa yes pair"	1,788	0.6%
purchase	order, purchase, buy	"order cascade dash button" "order the dog complete series dvd" "alexa order scrabble twist"	883	0.3%

Figure 1 – Content categories for Alexa commands. Keywords were used to categorize the 278,654 commands.

These were removed for a final dataset of 278,654 commands. Households on average had owned an Alexa device for 368 days based on their history logs.

To analyze the content of the 278,654 commands, we iteratively created a set of categories based on the in-person interviews and reviewing random samples of the gathered commands. From these categories, we extracted keywords and used string matching to categorize our entire dataset. We randomly sampled commands from categories to validate that the majority of commands in the category matched the category's intent. See Figure 1 for a summary of the categories we created.

In-Home Qualitative Interviews

In June and July 2017, two of the authors visited the homes of seven participants who had owned an Amazon Alexa device for more than three months. These seven households were recruited for the variety of their household arrangements, especially having young children interacting with the conversational agents (see Table 2 for a summary of the household compositions).

We used a semi-structured interview protocol. After a brief initial survey, we asked participants to tell us about their experiences with their conversational agents. We probed their experiences by asking specifically about moments of joy and frustration, moments where they socially interacted with the device, moments when their home environment influenced how they interacted with the device, experiences of children interacting with the device, and moments where they experienced questions about their privacy. All interviews lasted between 50 and 90 minutes. Participants were paid $20 for their time.

In addition to the semi-structured interviews, we asked users to engage in a number of generative activities. These activities were inspired by the generative activities used in participatory design [33]. These included sketching their conception of the Alexa ecosystem, viewing their most common commands, and using a police sketching application to create their idea of what Alexa might actually look like. These activities further evoked stories and views from the participants that the interview questions alone did not evoke.

After each interview, we debriefed participants. We then transcribed the interview and organized the results using affinity diagramming. We ended the study after seven interviews, as we had at that point begun to see repeated themes appearing in the interviews.

FINDINGS

Our study is one of the first to explore the question of how households incorporate conversational agents into their lives using both interview and scraped log data. We present the findings from the two studies together to give a sense of the themes we discovered. Several themes emerged as relevant for how households incorporated their Alexa devices. We have organized the themes into a rough chronological order of the user experience, starting with how people get used to the technology, where they physically locate their devices, and steady state patterns of use.

Theme 1 - Purchasing and Acclimating to Alexa

Much research has been done studying how people

	Products Owned	Family Composition	Length of Ownership
H1	1 Echo	1M, 1F	2 years
H2	1 Dot	1M, 1F	0.75 years
H3	1 Echo	1M, 1F, 2 visiting grandchildren	0.75 years
H4	1 Dot	1M, 1F	0.5 years
H5	1 Echo	2M, 1F, 2 children under four	1.5 years
H6	1 Dot	2M, 1F, 2 children under four	0.5 years
H7	Multiple	1M, 1F, 2 visiting grandchildren	2 years

Table 2 – Household data for in-home participants.

acclimate to new technology [19]. For most people, their Amazon Alexa is the first place-based conversational agent they have owned. We thus wanted to look at the experience of first purchasing the Alexa as well as how quickly people settled into routines.

Log Study Results

Based on the conversational logs, households' first few hours of interactions with Alexa look very different than their overall usage. For commands within the first four hours, 32% are either uncategorizable (versus 24% for all commands) or questions, mostly about Alexa 7% (versus 3.5% for all commands). In this initial period of exploration, only 4% of commands relate to smart home devices (compared with 14.7% for the entire set of commands. A sample of commands from this period include: "Alexa, tell us a joke," "Who was Santo Dumont?," "How high is Mount Whitney?," "Who is Trump?," "What movies are playing nearby?"

We also found that households quickly settled into a stable usage level. After a few days of experimentation, the level of usage remained constant week-over-week for the first year, as shown in Figure 2. While there is the problem of self-selection bias in our data sample, the long-term stability indicates how strongly Alexa is incorporated into these households' lives.

One small surprise for us is that many households own more than one Alexa device (specific numbers discussed in the next theme). For these households, we found that they slowly added additional devices over the course of years. See Figure 3 for a kernel density estimate graph of when households added additional Alexas (kernel density estimation is a common non-parametric method for estimating the distribution of a continuous variable, which overcomes some of the challenges of using a histogram [27]). For second devices, the median days from very first use (i.e. when the household activated its first device) was 130 days (mean: 172 days). For third devices, it was 233 days (mean: 261). For fourth devices: 336 days (mean: 377). So, households that chose to invest in the ecosystem added a new device every approximately 100 days.

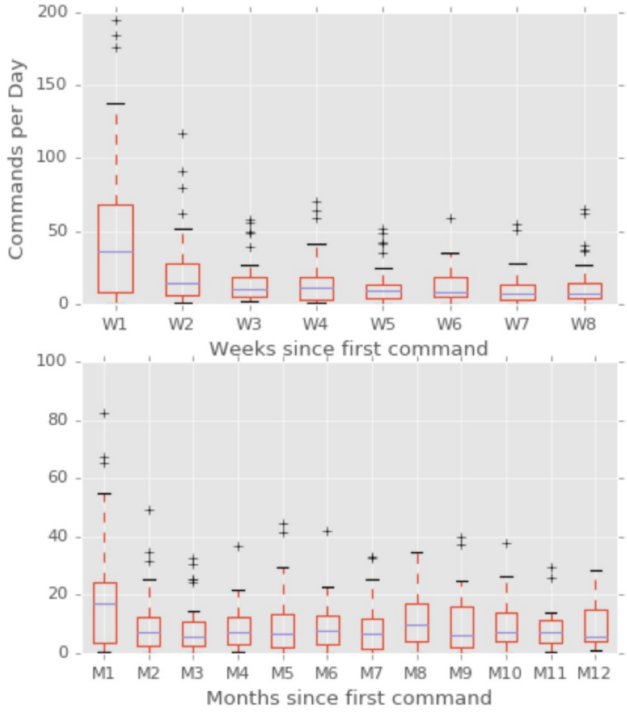

Figure 2 – Daily usage rates for 75 households.

At the same time, for households with more than five devices, there are multiple instances of households purchasing multiple Alexas simultaneously. Participant L57, for example, purchased a second device 239 days after the household's first purchase. Then they purchased four Amazon Dots 722 days after. L35 was given their second device 327 days after their first interaction. Then they were given their third device and purchased their fourth device within a month of each other 100 days later. Finally, they purchased two devices simultaneously 818 days after their first use.

In-Home Study Results

Many households told us memorable stories about first getting Alexa. Their Alexas were the first home-based conversational agent they had owned, though one participant had family members who encouraged her to get the device. Households talked about a period of excitement and exploration that quickly revealed the limits of the device, as well as a few uses that eventually turned into routines.

Households attempted to test Alexa in different ways to see how intelligent the device actually was. These tests fell into three types: personality, access to knowledge, and intellect. Personality tests involved seeing how naturally Alexa could respond to outrageous commands. Participant H2 asked if Alexa had a boyfriend. H1 quoted famous movie lines to it to see if Alexa would recognize that he was making cultural references. Access to knowledge tests involved asking factual questions that an internet search would quickly answer. H3 asked who took part in the War of 1812. H6 asked when a local

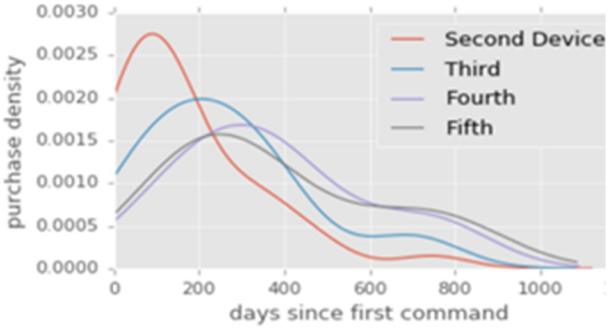

Figure 3 – Kernel Density Estimate of days after household's first command that other devices were first used.

botanical garden opened. H3 summarized her testing saying, *"I think I was trying to see how far she could go and I think I was trying to stop her. … [These] things I didn't really care about, but how smart is she anyway?"* Intellect tests involved seeing how sophisticated a command Alexa could understand. Multiple households mentioned attempting to come up with convoluted phrases to see if Alexa could handle those, for example asking about weather using different attributes (tomorrow's weather, next week's, a different city).

These initial tests were often performed in a social environment. When H1 first got their device, they video chatted their out-of-town family members and together attempted to use Alexa via the video's audio feed. This finding correlates with previous research showing that when multiple users within a family ecosystem interact with a conversational agent, satisfaction is higher [31]. H4 opened his Alexa at his parents' house and everyone attempted to interact with it: *"It was like one of those things when you're trying to talk to it and a lot of people are talking to it so it doesn't understand most of the time. Because everyone's trying to talk to talk to her, tell her to do this!"* Every adult member of the H5 household together went through voice training with Alexa, which together exposed them to Alexa's primary features.

Supporting our finding from the log data, this period of experimentation and excitement was short-lived. "We've spent probably the first week or so really testing it to see what I can do with the Alexa period what kind of questions can we ask it. But after that I pretty much use it only for three things" [H6]. However, most of the in-home participants could not pinpoint a particular moment when the excitement ended.

Theme 2 - Physical Placement of Devices

Conversational agents connected to smart speakers are uniquely connected to the rooms they are placed in. Unlike personal assistants on smartphones, these devices cannot travel with the user. Because they lack a screen and their physical footprint is small, a user must have a felt sense that the conversational agent is available in a particular space. For these reasons, we looked at what environments households were placing their Alexas in and how those choices affected use.

Log Study Results

The majority of our participants owned more than one device (mean: 2.71 devices, min: 1, 25%: 2, 50%: 2, 75%: 3, max: 11). Previous surveys have reported that 42% of Alexa owners own more than one device, but it appears that our sample includes more enthusiasts who are invested in Alexa's ecosystem [29].

The types of Alexa devices owned were diverse. 68% of households owned the Amazon Dot (retailing for $49.99, and the most inexpensive dedicated Amazon voice recognition product). The full-sized Amazon Echo was second with 53.3% of households owning one (retailing for $179.99, and the second most expensive Amazon device). Amazon's Fire TV (retailing for $39.99), a device that adds intelligent features to television sets, was in use in 21.3% of homes. Non-Amazon products were present in 12% of households.

We found our participants had Alexa devices in a variety of rooms. While previous surveys have reported that the majority of Alexa owners have their devices placed in the kitchen [32], our survey found that the bedroom was the most common location for Alexa, followed closely by the living room and then the kitchen. Crabtree and Tolmie found that physical objects and technology in the home support geographically disparate routines, but that the kitchen and bedroom have distinct and contained routines [9]. It appears that the placement of Alexa in these rooms is for the completion of particular goals, while location in shared spaces like the living room opens the Alexa to more open-ended uses.

Those households with more Alexa devices did have more interactions per day, as Figure 4 shows. For households with one or two devices, the average per-day, per-user median number of commands was 6.04. For households with three or four devices, it was 10.39, and for five and six it was 14.42.

Alexa also offers controls for smart home devices. Users can register an Internet of Things light, speaker, or other compatible device with their family of Alexa devices. They can then control them through the Alexa interface. As they register the devices, they must give them a name, for example, "kitchen entrance lamp" or "hallway fan." These labels give us insights into where people are placing their Internet of Things devices. Based on word frequencies of categories labeled as "smart home" (see the next section for details on categorization), the most common rooms for IoT objects was the living room, bedroom, kitchen, family room, "downstairs," nightstand, dining room, ceiling, den, office, and overhead. The most popular devices that were controlled were lights, fans, and televisions. The most common actions performed were turning devices on and off, and setting or dimming devices to a particular percent level. We also found that households with more Alexa devices appear to use more smart home commands indicating that their Alexa was one component of a larger ecosystem of devices that they had chosen to invest in.

In-Home Study Results

Our in-home study findings closely followed the log study: six of our participants owned one device, either an Echo or Dot, and placed them in the kitchen, bedroom, or living room. One household had at least seven devices spread throughout their entire household.

All participants discussed the limits of their physical awareness of Alexa. Typically, this awareness matched

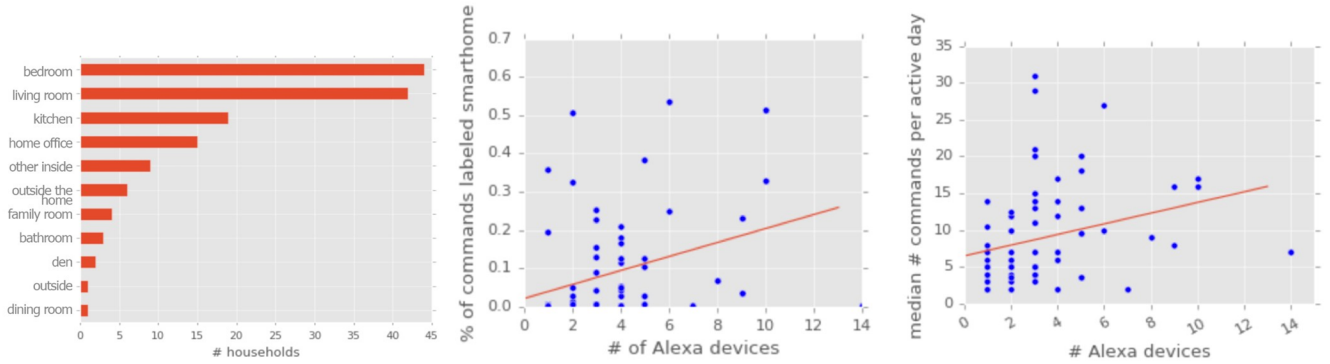

Figure 4 – L: Bedrooms were the most common location for Alexa devices with 44 households having an Alexa in a bedroom. C: Households with more Alexa devices use more smart home commands, indicating a wider investment in smart home technology. R: Owning more Alexa devices resulted in a higher number of interactions per day.

their line of sight of the physical device. H4 mentioned walking from the living room to the doorway of the kitchen, where the Alexa was located, to engage with it. H1 told how they needed to see Alexa acknowledge their request with its blue light ring before they finished their request. H1's husband who also participated noted how he did not need to see Alexa if he was giving a command from a weight scale he had. Because he regularly weighed himself and recorded it using Alexa, he knew that Alexa would be able to hear him.

Because of Alexa's small physical profile, none of the participants mentioned that visitors had an awareness of their Alexa devices. Households did have experiences proudly showing off Alexa to visitors by playing the game Twenty Questions (H4), asking it humorous questions (H1), or having it do rudimentary tasks like playing music or setting a timer (H2). But it was a household member who introduced the device. The novelty of Alexa also appeared to wear off very quickly for visitors. Only one household, H5, mentioned a negative experience from introducing Alexa. A visiting family member requested that the device be unplugged because the relative was concerned that the device was recording their conversations.

The household with the seven Alexa devices slowly accrued devices. They started with the full-sized Echo. Then were then given an Amazon Dot. They liked how they sounded, and they purchased smart bulbs and light switches and enjoyed the experience of controlling them with their two Alexas. After owning two, they decided to purchase multiple of the less expensive Dots with the aim of having complete coverage. They mentioned having devices in their kitchen, home office, TV room, living room, exercise room, and bedrooms.

The household felt that the full household coverage did affect their awareness of the devices. In our interview, both the husband and wife mentioned that they hated lights and screens that intruded on their private space. They thus placed all their Alexas in places hidden from direct view, such as on top of a kitchen shelf, on the lower level of a nightstand, and on a book shelf. Despite never seeing their Alexas, their ubiquity gave them the confidence that at Alexa would hear their command.

In addition to affecting their awareness, the multi-device family felt that full coverage also affected the kinds of interactions they were having with Alexa. As they added Alexas, they had also invested in Internet of Things devices, especially lights. They also noted that were quicker to ask it questions and use its list feature: *"I think that ubiquity, you start to gradually start to realize*

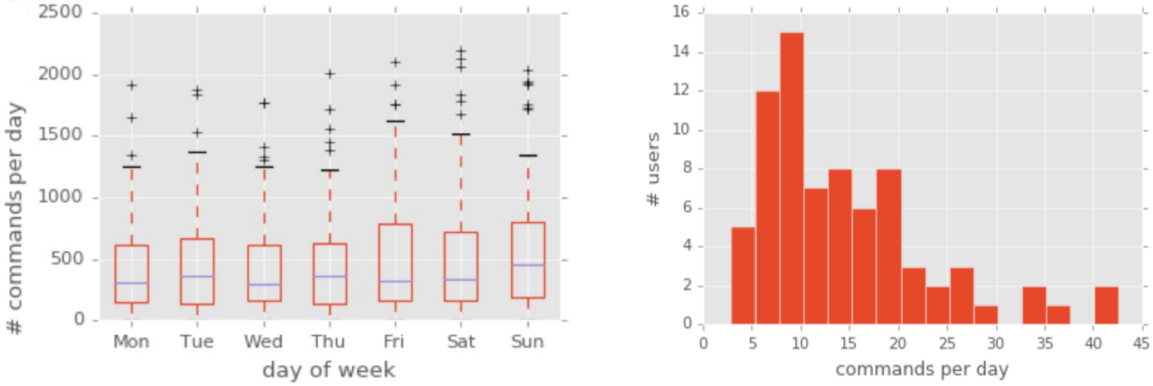

Figure 5 – L: Number of commands across all households per day (one outlier excluded). Participants used their Alexa devices almost every day of the week and no single day was more popular than others. R: Average number of commands per day per household. The number of commands varied greatly across households.

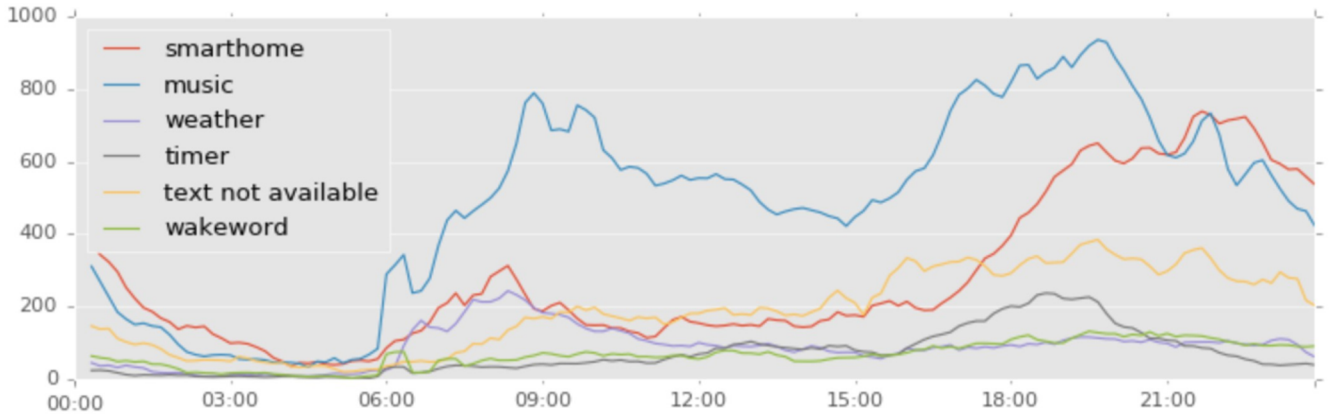

Figure 6 – Counts of some categories over the course of the day, binned into 10 minute intervals

that that opens up different use cases. Like the shopping list thing. Once there's usually one within earshot then it's just completely compelling. Of course you should keep that list there" [H7]. They noted that ubiquity allowed them control any lights from any rooms. This did cause some problems if both of the couple were trying to control one light. The husband noted that instead of checking the time on his smartphone, he now just asks Alexa whenever he wishes to know what time it is. He knows Alexa is always available, while he would have to look for his phone.

Theme 3 - Daily Patterns of Conversational Usage

In this section, we look at how the time of the day affects household conversational agent usage.

Log Study Results

Participants used their Alexa devices almost every day, but the number of commands they gave varied greatly across households, as Figure 5 illustrates. On days when at least one command was given, the average number of commands from each user varied from 2.8 commands per day to 42.5 commands per day (mean: 14.3 commands per day, 25%: 8.2, 50%: 11.2, 75%: 18.5).

Over the course of the day, the rate of usage peaked in the morning before 9am local time, and then peaked again in the late evening. Unsurprisingly, the least popular time to talk to Alexa was late at night.

Just as total commands changed, particular categories rose and fell as well. Figure 6 shows a 24-hour timeline of various categories across all data. Music, the most common category, had similarly-sized spikes in the morning and evening. Smart home commands had a small spike in the morning, but a much larger spike in the evening and night. Some categories had particular moments in the day that they spiked: weather was asked in the morning and timers were set in the evening, probably around food preparation.

While it is hard to be entirely sure when Alexa misfired and began recording an interaction, we can look at moments where Amazon was unable to transcribe any and commands that consisted only of a wakeword without any follow up command. We saw these two categories occur throughout the day, though the inability to transcribe increased in the evening. These two categories accounted for 13.2% of all commands indicating that either misfires or miscomprehension is a very common occurrence.

In-Home Study Results

Analysis of the logs showed that people use their Alexa devices almost every day, with patterns in terms of time of day. Our home interviews indicated the importance of developing and breaking routines for Alexa usage.

For the in-home participants, Alexa naturally integrated with their morning routines. Because Alexa is hands-free and does not demand full attention, people mentioned using Alexa when feeding children, getting dressed, showering, and making coffee. One typical response was from H6: *"I use it for checking the weather. Almost every morning. It's my favorite way to check the weather. I used to look at my phone and now I even prefer asking Alexa while getting my morning coffee."* For some participants, the integration occurred immediately, but for others, the morning routine has continued to evolve months or years since getting Alexa. H7 noted that it had taken him 1.5 years of owning his Alexa before he began asking Alexa about the weather in the morning. The change had occurred because unseasonable rains made his morning commute unexpectedly difficult.

In addition to morning routines, participants reported routines around taking care of children, playing musical instruments, cooking meals, and getting ready for bed. In some cases, Alexa's abilities fit the routine well. H5 used Alexa to set a timer for her children's afternoon naps. During nap time, she used Alexa to add groceries to her list as well as other timers to time the amount of housework she did. For others, Alexa integrated into their routines despite Alexa's failures. H4, an amateur musician, initially purchased Alexa for its integration with music services. "So I sit there with my guitar and I would play I'm learning a song and I would say 'Alexa Play the song again.' So my initial thing was it's really cool because I don't have to type it in. But if it's hooked up to Spotify you can't say 'Alexa

start over' you literally have to repeat the whole song again. At least as far as I know" [H4]. Despite the trouble, he continued to use Alexa despite acknowledging it would be easier to use his laptop. H1 had a similar experience with the value of Alexa's hands-free nature integrating into his morning routine. Though he had to yell across his apartment, he recorded his daily weight using Alexa instead of his smartphone because it was easier for Alexa to record it than to use his smartphone.

Routines supported Alexa usage, but were dynamic and could end quickly. H2 lost electricity for three days, and the couple quit using Alexa's alarms because they felt they could not trust Alexa's reliability. H2 and H4 both noted how changes in employment affected who used the Alexa in the morning. H2 moved their Alexa from the kitchen to bedroom, which changed their interactions with Alexa from general usage to a strong morning and nighttime routine. H6 moved their home desktop computer from the living room to a bedroom, and playing music in the living room shifted to their Alexa.

Theme 4 - Children and Conversational Agents

One unexpected theme that came out from our studies was how children use Alexa. Many of our participants discussed this unprompted, and mentioned some unique design opportunities and challenges.

Log Study Results

26 of 75 participants reported having children from the log study, though we did not ask their specific ages. Unfortunately, Alexa does not currently differentiate amongst users, and the log data does not provide any insights into which household members gave each command, so extracting insights about how children use conversational agents is currently not possible.

However, some participants mentioned children in their open-ended responses. Six of the participants recounted a positive experience involving their children. Parents positively recalled their children successfully interacting with the device (*"When my daughter asked how to spell things"* [L211], *"I most like when she can understand my children. They like to request music…"* [L135], *"My kids love to experiment with talking to Alexa"* [L231]). This correlates with prior research that children often attribute intelligence and social skills to conversational agents [31]. Parents also positively recalled using Alexa to play music for children, either for going to sleep or for dancing. Two parents mentioned a negative experience with their children. One brought up Alexa's inability to understand their children's vocal cadence and the other mentioned Alexa being unable to pronounce their daughter's name.

In-Home Study Results

Four of the seven households participating in the in-home study had children interact with Alexa. Two families had small children and two had grandchildren who regularly visited. Their stories support the limited findings from the log study, that parents derive joy from watching their children interact with Alexa, but children have difficulty interacting with Alexa.

Parents mentioned moments of joy watching their children interact with Alexa. H6 recounted a dance party her son initiated with Alexa: *"And he got the music up pretty high. He was really excited. And we had a dance party in the kitchen that he initiated. And that was so cool. I really enjoyed that."* H5 said that her daughter recently discovered that while listening to music, she could tell Alexa that she liked the song or could skip it. While this made her feel happy, she was also chagrined because her child had discovered a way to skip songs the parent liked but the daughter did not. Two parents mentioned that they enjoyed watching their older children ask Alexa for factual information. H6 mentioned Alexa answering the question, "Why is the sky blue?" and H3 said how their grandson loved airplanes and asked questions about how many planes flew between two cities.

Parents said that their children started interacting with Alexa at a very young age, and that these interactions affected how their children interacted with other technology. H5 noted their 15-month son knew to look towards Alexa when a family member interacted with Alexa. Their older child was 2.5 years old when the family purchased their Alexa and the daughter immediately began interacting with it.

While children began interacting with Alexa at a young age, children's verbal intonations and cadences made commanding Alexa a skill to be mastered. *"He just didn't have the knack for pausing. Saying 'Alexa… pause.' … I think he's finally figured out that cadence you have to wait a second for it to respond."* [H6]. In addition to cadence, understanding the limits of Alexa's knowledge of the home environment was also challenging for children. H5's child assumed Alexa could see the color of crayons and paint in front of the child during playtime when she asked Alexa what color crayon she was using.

Finally, the fact that Alexa is a conversational agent affected how children interact with parents and others. As mentioned earlier, H5's daughter has learned she can command Alexa to skip songs she dislikes over the objections of her parents. More generally, H5's daughter was more comfortable seeing Alexa as a full person than her parent, to the point of befriending it. *"So my daughter thinks she knows Alexa's habits and she can understand Alexa even if I can't. It's kind of creepy. As I say it out loud it's totally weird that my daughter is friends with a tower that sits on my counter"* [H5]. H3 felt more comfortable letting her grandchildren interact with Alexa compared to a smartphone because it's a public experience shared with the whole family. When

one grandson told Alexa it was "stupid," she corrected him. *"I said that's not nice. I mean this is not a person we all know but I just didn't like the fact that he was doing that"* [H3].

DISCUSSION AND FUTURE WORK

Our work offers a rich description of how people are using conversational agents and how they are integrating it into daily life. Home life has a daily rhythm from waking up in the morning, leaving for the day, coming home, entertaining, and going to sleep. As conversational agents intersect with these different moments, users interact differently with them. Here, we discuss some opportunities to improve the design of these devices.

Data mining to offer new features. The lack of new feature discoverability limited experimentation with and increase in how people used Alexa. The lack of audio and visual affordances coupled with the lack of any hook beyond preexisting routine make the design of discovering new features a significant challenge for conversational user interfaces. As we saw in our studies, people explored Alexa's functionality a great deal on initial use, but did not often try new functionality afterward. One possible opportunity is to data mine repeated patterns of use or use common routines (such as morning prep, cooking, and bedtime) as scaffolding to introduce new related features. For example, H4 used his Alexa to support his musical practice by repeatedly playing the same song. Alexa could have recognized this and suggested additional training skills to install. While Amazon does have some discovery features, based on the authors' personal experiences, they focus on topical daily events—often awards shows, entertainment, and sports—instead of understanding users' routines.

Leverage knowledge of place. The fact that Alexa does not travel with a person like a laptop or smartphone meant that usage of Alexa was also bound with place-based routines. Conversational agents lack a sense of place and what activities transpire in those places. By leveraging knowledge that an agent is in a living room versus a bedroom, it can modify its level of proactivity, listen for particular commands, and offer more appropriate suggestions for new uses. While we did not do so in this paper, we believe it is possible to identify the location of a device based on kinds of commands and what time those commands are used. Of course, the device could also just ask the user where they have placed it as well.

Integrate connected devices. While a large majority of people in the United States own smartphones, we found very few references of any complementary uses between conversational agents and smartphones in our in-home interviews. For instance, Amazon offers an Alexa smartphone app, but it only offers rudimentary functionality in the form of showing lists, musical controls, and device settings. As a concrete example, cooking routines are well supported both by Alexa and by recipe apps, but not together. If the recipe app could be controlled by speech, it would enable hands-free recipe management. There are many such possibilities to tightly integrate not only smartphones but also connected televisions, computers, and other screen-based devices.

Influence of CUIs on children. Parents mentioned apprehension about seeing their very young children interacting with Alexa, even before interacting with smart phones and other technology. One imperative is for those designing and developing this technology to understand the impact that conversational agents are likely having on children. As our in-home interviews showed, very young children are highly influenced by the spoken nature of conversational agents, respond to the agents at a very young age, and imbue the agent with human-like qualities. It is unclear how interacting with conversational agents at a young age will affect children's social awareness, but it is something the parents we interviewed were concerned about. Another path here is to design new kinds of conversational experiences explicitly for children. Some speculative examples might include helping young children learn how to read or spell words better, helping school age children study and practice drills, or more kinds of social games to foster more interaction with others in the room rather than having children speak only to the conversational agent.

LIMITATIONS

The primary limitation of this work is the composition of participants. In-home interviews were primarily with relatively affluent, urban families. Log study participants were self-selecting and clearly skewed towards enthusiasts of Alexa. Users who had quit using Alexa were not covered. Their stories would provide useful insights into the failures of the Alexa ecosystem. Future work needs to explore greater participant diversity.

CONCLUSION

In this paper, we presented two complementary studies that investigate how households incorporate the Alexa conversational agent into their homes. In our first study, we gathered and analyzed Alexa history logs from 75 users. In our second study, we interviewed people from seven households to richly understand their experiences with the devices. From these sources, we organized our findings into four main themes: how people initially use and purchase Alexa, where people physically locate their devices, what kinds of commands people use and routines people have in steady state use, and how children interact with Alexa. Our findings reveal how this technology can integrate into people's lives, and offers suggestions for improvement with future designs.

REFERENCES

1. Sameera A. Abdul-Kader and John Woods. Survey

on Chatbot Design Techniques in Speech Conversation Systems. *International Journal of Advanced Computer Science and Applications* 6, 7. http://doi.org/10.14569/IJACSA.2015.060712

2. Gregory D. Abowd and Elizabeth D. Mynatt. 2000. Charting past, present, and future research in ubiquitous computing. *ACM Transactions on Computer-Human Interaction* 7, 1: 29–58. http://doi.org/10.1145/344949.344988

3. Gregory Abowd, Keith Edwards, and Beki Grinter. 2003. Smart homes or homes that smart? *ACM SIGCHI Bulletin - a supplement to interactions* 2003: 13–13. http://doi.org/10.1145/967199.967215

4. Bayan Abu Shawar and Eric Atwell. 2007. Chatbots: are they really useful? *LDV Forum*. Retrieved September 17, 2017 from https://www.researchgate.net/profile/Eric_Atwell/publi cation/220046725_Chatbots_Are_they_Really_Useful/ links/00b7d518ab7329add2000000/Chatbots-Are-they- Really-Useful.pdf

5. Corey Badcock. 2015. First Alexa Third-Party Skills Now Available for Amazon EchoNo Title. *Alexa Blog*. Retrieved from https://developer.amazon.com/blogs/post/TxC2VHKF EIZ9SG/First-Alexa-Third-Party-Skills-Now-Available-for-Amazon-Echo

6. Izak Bensabat and Weiquan Wang. "Trust in and adoption of online recommendation agents." *Journal of the association for information systems* 6, no. 3 (2005): 4

7. Justine Cassell, Timothy Bickmore, Mark Billinghurst, Lee Campbell, Kenny Chang, Hannes Vilhjálmsson, and Hao Yan. "Embodiment in conversational interfaces: Rea." In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems*, pp. 520-527. ACM, 1999.

8. Justine Cassell, Tom Stocky, Tim Bickmore, et al. 2002. MACK: Media lab autonomous conversational kiosk. *Proceedings of Imagina '02*.

9. Marshini Chetty, Ja-Young Sung, and Rebecca E. Grinter. 2007. How Smart Homes Learn: The Evolution of the Networked Home and Household. 127–144. http://doi.org/10.1007/978-3-540-74853-3_8

10. Andy Crabtree and Tom Rodden. Domestic Routines and Design for the Home. *Computer Supported Cooperative Work (CSCW)* 13, 2: 191–220. http://doi.org/10.1023/b:cosu.0000045712.26840.a4

11. Andy Crabtree and Peter Tolmie. 2016. A Day in the Life of Things in the Home. *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing - CSCW '16*, 1736–1748. http://doi.org/10.1145/2818048.2819954

12. Scott Davidoff, Min Kyung Lee, Charles Yiu, John Zimmerman, and Anind K. Dey. 2006. Principles of Smart Home Control. In *Proceedings of the 8th international conference on Ubiquitous Computing*. Springer-Verlag, 19–34. http://doi.org/10.1007/11853565_2

13. Stefania Druga, Randi Williams, Cynthia Breazeal, and Mitchel Resnick. 2017. "Hey Google is it OK if I eat you?": Initial Explorations in Child-Agent Interaction. *Proceedings of the 2017 Conference on Interaction Design and Children - IDC '17*, ACM Press, 595–600. http://doi.org/10.1145/3078072.3084330

14. Homer Dudley. 1939. Remaking Speech. *The Journal of the Acoustical Society of America* 11, 2: 169–177. http://doi.org/10.1121/1.1916020

15. W. Keith Edwards and Rebecca E. Grinter. 2001. At Home with Ubiquitous Computing: Seven Challenges. *Proceedings of the 3rd international conference on Ubiquitous Computing*, Springer, 372. Retrieved September 16, 2017 from http://dl.acm.org/citation.cfm?id=741327&CFID=9850 43092&CFTOKEN=74478828

16. Darrell Etherington. 2014. Amazon Echo Is A $199 Connected Speaker Packing An Always-On Siri-Style Assistant | TechCrunch. *Techcrunch*. Retrieved September 15, 2017 from https://techcrunch.com/2014/11/06/amazon-echo/

17. Adjamir M. Galvao, Flavia A. Barros, Andre M. M. Neves, and Geber L. Ramalho. 2004. Persona-AIML: An Architecture Developing Chatterbots with Personality. *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems - Volume 3*: 1266–1267. http://doi.org/10.1109/aamas.2004.208

18. Juan Pablo Garcia Vazquez, Marcela D. Rodriguez, and Angel G. Andrade. 2010. Design dimensions of ambient information systems to assist elderly with their activities of daily living. *Proceedings of the 12th ACM international conference adjunct papers on Ubiquitous computing - Ubicomp '10*, ACM Press, 461. http://doi.org/10.1145/1864431.1864487

19. William Gaver, Alex Wilkie, Andy Boucher, et al. 2008. Threshold devices. *Proceeding of the twenty- sixth annual CHI conference on Human factors in computing systems - CHI '08*, ACM Press, 1429. http://doi.org/10.1145/1357054.1357278

20. Lars Gesellensetter, Nicole C. Krämer, and Ipke Wachsmuth. 2005. A conversational agent as

museum guide - Design and evaluation of a real-world application. *THE 5TH INTERNATIONAL WORKING CONFERENCE ON INTELLIGENT VIRTUAL AGENTS (IVA '05)*, Springer, 329–343. Retrieved March 5, 2017 from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.93.7488

21. Evangelos Karapanos, John Zimmerman, Jodi Forlizzi, and Jean-Bernard Martens. 2009. User experience over time: an initial framework. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*: 729–738. http://doi.org/10.1145/1518701.1518814

22. Stefan Kopp, Lars Gesellensetter, Nicole C. Krämer, and Ipke Wachsmuth. "A conversational agent as museum guide–design and evaluation of a real-world application." In *International Workshop on Intelligent Virtual Agents*, pp. 329-343. Springer, Berlin, Heidelberg, 2005.

23. Gustavo López, Luis Quesada, and Luis A. Guerrero. 2018. Alexa vs. Siri vs. Cortana vs. Google Assistant: A Comparison of Speech-Based Natural User Interfaces. . Springer, Cham, 241–250. http://doi.org/10.1007/978-3-319-60366-7_23

    Farhad Manjoo. 2015. Amazon Echo, a Personal Assistant in Need of Some Schooling. *New York Times*, B8. Retrieved from https://www.nytimes.com/2015/06/25/technology/pers onaltech/amazon-echo-aka-alexa-is-a-personal-aide-in- need-of-schooling.html

24. Sven Meyer and Andry Rakontonirainy. 2003. A survey of research on context-aware homes. *Proceedings of the Australasian information security workshop conference on ACSW frontiers 2003 - Volume 21*, Australian Computer Society, 90. Retrieved September 13, 2017 from http://dl.acm.org/citation.cfm?id=828005

25. Kris Nagel, Cory D. Kidd, Thomas O'Connell, Anind Dey, and Gregory D. Abowd. 2001. The Family Intercom: Developing a Context-Aware Audio Communication System. . Springer, Berlin, Heidelberg, 176–183. http://doi.org/10.1007/3-540-45427-6_14

26. William Odom, John Zimmerman, Jodi Forlizzi, Hajin Choi, Stephanie Meier, and Angela Park. 2012. Investigating the presence, form and behavior of virtual possessions in the context of a teen bedroom. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*: 327–336. http://doi.org/10.1145/2207676.2207722

27. Gerard Oleksik, David Frohlich, Lorna M. Brown, and Abigail Sellen. 2008. Sonic interventions. *Proceeding of the twenty-sixth annual CHI conference on Human factors in computing systems - CHI '08*, ACM Press, 1419. http://doi.org/10.1145/1357054.1357277

28. Charles L. Ortiz. 2014. The Road to Natural Conversational Speech Interfaces. *IEEE Internet Computing* 18, 2: 74–78. http://doi.org/10.1109/MIC.2014.36

29. Emanuel Parzen. On Estimation of a Probability Density Function and Mode. *The Annals of Mathematical Statistics 33*, 1065–1076. http://doi.org/10.2307/2237880

30. Sarah Perez. 2017. Amazon to control 70 percent of the voice-controlled speaker market this year. *Techcrunch*.

31. Sarah Perez. 2017. 42 percent of smart speaker owners have bought a second device (or more) | TechCrunch. *Techcrunch*. Retrieved September 15, 2017 from https://techcrunch.com/2017/06/23/42-percent-of- amazon-echo-owners-have-bought-a-second-device-or- more/

32. David Powers, Richard Leibbrandt, Martin Luerssen, Trent Lewis, and Mike Lawson. 2008. PETA. *Proceedings of the 1st ACM international conference on PErvasive Technologies Related to Assistive Environments - PETRA '08*, ACM Press, 1. http://doi.org/10.1145/1389586.1389658

33. Amanda Purington, Jessie G. Taft, Shruti Sannon, Natalya N. Bazarova, and Samuel Hardman Taylor. 2017. "Alexa is my new BFF": Social Roles, User Satisfaction, and Personification of the Amazon Echo. *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems - CHI EA '17*, ACM Press, 2853–2859. http://doi.org/10.1145/3027063.3053246

34. Jason Del Rey. 2016. You're not alone: 51 percent of Amazon Echo owners have it in the kitchen. *Recode*.

35. Douglas. Schuler and Aki. Namioka. 1993. *Participatory design : principles and practices*. L. Erlbaum Associates. Retrieved September 18, 2017 from http://dl.acm.org/citation.cfm?id=563076

36. Yankelovich and Nicole. 1996. How do users know what to say? *interactions* 3, 6: 32–43. http://doi.org/10.1145/242485.242500