
# PIA

# Understanding the Influence of Digital Assistants' Physical Design on Trust and Privacy

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# Preface

This report is the product of our Master's thesis at Aalborg University finalizing our degree of Masters of Science in Informatics. This thesis is a continuation of our 9th semester project, called *Trust in Digital Assistants: A Literature Review,* which was a literature review of trust. First a literature review exploring trust factors, followed by another literature review discovering these trust factors in papers exploring digital artefacts. Findings from the 9th semester project will be referred to in this thesis, serving as background knowledge or reference. It will be clearly stated when used.

The title of the Master thesis is "PIA: Understanding the Influence of Digital Assistants' Physical Design on Trust and Privacy", and was written under the theme Human-Computer Interaction in the period from 1st of February to 11th of June year 2019. The designated group was HCI1012f19, and included three students from Informatics at Aalborg University.

We want to give a special thanks to our supervisor Dimitrios Raptis for helping us throughout this thesis and prior projects. Another thanks to the participants willing to participate in our field study for this thesis.

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# Summary

Digital artefacts are becoming more and more present in everyday life and activities. The artefacts are build smarter and more connected creating an ecology of devices. Users are growing fond of the functionality and convenience of these devices, however they also compose a problem of trust and privacy. The devices often require credentials before they can be used properly, and they make use of logging activities. This is a problem as data leakage or functionality failure can result in users being exposed or miscredited [6].

In a literature review in our 9th semester project we derived 28 factors relating to trust [2], which were divided into nine clusters. It was then explored if these 28 factors have been explored in regards to digital assistants, as these artefacts are growing massively in sales and rise in popularity [3]. Digital assistants are referring to artefacts as Google Home, Amazon Echo and Apple Homepod. It was found that not all 28 factors of trust had been explored in regards to digital assistants. Hence, we chose to dive into these.

Our 10th semester Master's thesis explores if it is possible to affect user's trust and privacy in digital assistants by altering their physical design. *Physical Design* was one trust factor we extracted in our literature review that was not explored specifically in regards to commercial digital assistants. We decided to develop a prototype digital assistant, designed with inspiration from provocation design in mind [1]. The prototype was called PIA (Privacy Invasive Assistant), and made use of a Raspberry Pi with the Google Assistant Library implemented. Furthermore, a microphone, a speaker, an LED, a servo engine and an LCD screen was incorporated. All the hardware was placed inside an old cassette recorder. The purpose was to make a prototype that became more visible and emphasized the recording of voice to users, and not blend in with its surroundings as many digital artefacts do today [4].

Our findings show that we were able to make users more aware of the digital assistant, and make them reflect more on the fact that digital assistants record their interactions. The prototype was referred to as spooky, and it was stated that it was scary information it visualized. However, the usage pattern between our participants were quite similar to their normal use, both in frequency and categories of use. Users told that although they started to reflect on the presence of the digital assistant they ranked its convenience and functionality above trust and privacy.

# Summary (Danish Version)

Digitale artefakter bliver mere og mere en del af menneskers hverdag og aktiviteter. Artefakterne bliver klogere og mere forbundet, hvilket skaber et økosystem af enheder. Brugere vender sig til funktionaliteten og bekvemmeligheden af disse enheder, men de udgør også et tillids- og privatlivsproblem. Enhederne kræver ofte legitimationsoplysninger, før alle funktioner kan anvendes, og de gør brug af logningsaktiviteter. Dette er et problem, da data lækage eller funktionalitetsfejl kan resultere i, at brugerne bliver udsat eller misbrugt [6].

I et litteraturstudie i vores 9. semesterprojekt afledte vi 28 faktorer vedrørende tillid [2], som blev opdelt i ni klynger. Det blev derefter undersøgt, om disse 28 faktorer er blevet undersøgt med hensyn til digitale assistenter, da salget af disse enheder vokser massivt og stiger i popularitet [3]. Digitale assistenter henviser til enheder som Google Home, Amazon Echo og Apple Homepod. Det blev fundet, at ikke alle 28 faktorer af tillid var blevet udforsket med hensyn til digitale assistenter. Derfor valgte vi at dykke ned i disse.

Vores 10. semester Speciale afhandling undersøger, om det er muligt at påvirke brugernes tillid og privatliv i digitale assistenter ved at ændre det fysiske design. Fysisk design var en tillidsfaktor, som vi udledte i vores litteraturstudie, der ikke blev udforsket specifikt med hensyn til kommercielle digitale assistenter. Vi besluttede at udvikle en digital assistent prototype, designet med inspiration med provokationsdesign i tankerne [1]. Prototypen blev kaldt PIA (Privacy Invasive Assistant) og udnytter en Raspberry Pi med Google Assistant Library implementeret. Desuden blev der indbygget en mikrofon, en højttaler, en LED, en servomotor og en LCD-skærm. Alt hardware blev placeret inde i en gammel kassettebåndoptager. Formålet var at lave en prototype, der blev mere synlig og fremhævede optagelsen af stemme-interaktion for brugere og ikke går i ét med dens omgivelser, som mange digitale artefakter gør i dag [4].

Vores resultater viser, at vi var i stand til at gøre brugerne mere opmærksomme på den digitale assistent, og fik dem til at reflektere mere over, at digitale assistenter registrerer deres interaktioner. Prototypen blev omtalt som uhyggelig, og der blev udtalt, at det var skræmmende information, den visualiserede. Brugsmønsteret hos vores deltagere var imidlertid ganske ligne deres normale brug, både i frekvens og anvendelseskategorier. Brugere fortalte, at selv om de begyndte at reflektere mere over tilstedeværelsen af den digitale assistent, rangerede de dens bekvemmelighed og funktionalitet over tillid og privatliv.

# PIA: Understanding the Influence of Digital Assistants' Physical Design on Trust and Privacy

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## ABSTRACT

In recent years consumers are accepting increasingly more digital artefacts into their homes. These artefacts are becoming incorporated into daily routines and blend in to their surroundings. Digital Assistants as Google Home and Amazon Echo are examples of such artefacts as they are always ON listening for wake-words. But placing these always listening artefacts into households may expose trust and privacy issues. This paper explores if users can be affected by altering the physical design of a digital assistant. Provocation was used to design a prototype called PIA (Privacy Invasive Assistant), which was deployed in households. It was found that users did become more aware of owning and using a digital assistant, however their usage remained similar prior to deployment of PIA. We conclude that it is possible to alter users' perception of trust and privacy in relation to digital assistants, but a more provocative design might be needed to change their usage.

## CCS CONCEPTS

• **Human-centered computing** → **Field studies**; • **Security and privacy** → *Privacy protections*; *Social aspects of security and privacy*.

## KEYWORDS

Privacy, Trust in Digital Artefacts, Digital Assistants, IoT, Smarthome

## 1 INTRODUCTION

Digital Assistants (DA) are becoming widely adopted into consumer products such as smartphones, PCs, smarthome devices and cars [23].

DAs can utilize several interaction modalities as seen on smartphones and PCs where visual and audio modalities are primarily used [9, 26, 30]. Other modalities can also be utilized e.g. Kim et al. [15] researched thermal indication as a means of interaction. DAs can also be stationary voice-only devices as is the case with Amazon Echo, Google Home and Apple Homepod which utilize voice as an interaction modality, and makes it possible to interact 'hands free' [22, 36]. We will refer to these devices as physical DAs. They were introduced by Amazon in 2014, described as an always-on connected speaker listening for commands [8]. The increasing popularity of DAs is apparent. Since 2014 the sales have grown massively for physical DAs with an increase every year since the introduction, selling 86.2 million devices globally in the year of 2018, with Amazon and Google being the most popular [14].

The term 'Digital Assistant' is broadly used for a multiplicity of meanings, like customer service chatbots on websites, voice assistants on smartphones, and IoT smarthome devices. Our definition of a DA is based on earlier research conducted by the authors on DAs [13]. In this paper we use the term DA as:
*An AI-enabled artifact that utilises natural language to interact with users and perform activities.*

The primary reason for acquiring DAs is their convenience as they are always available and may be used for multitasking [25, 29, 39]. However, this 'always available helper' might be a threat to data being used in other ways than just for performing tasks by the DA. DAs introduces some concerns regarding usage in public spaces [21] as well as privacy concerns in the home [16]. There are already reported several instances of users having data from their DA leaked to unwanted receivers [17, 32, 34]. Additionally, concerns for having a sound recorder in your home, not knowing when it starts and stops recording is a rising issue [4, 33]. A literature review conducted by the researchers found that the physical design is one of many factors to convey trust [13]. This literature review showed that the physical design of DAs have only gotten sparse attention in research papers [13]. The motivation for this project is to explore if it is possible to change the user's perception of trust and privacy, when altering the physical design.

To explore this, we developed PIA (Privacy Invasive Assistant), a physical DA prototype, with the looks of an old tape recorder to make the recording functionality more visible than in commercial physical DAs. This draws on thoughts from [20] stating that artifacts are becoming 'invisible' to users, which we want to challenge with PIA. PIA was evaluated by three households, where their usage patterns were analyzed and compared between their normal DA and PIA. It was found that while the physical design had an impact on users, the usage of their devices did not change in frequency, nor would they be willing to trade their DAs in exchange for more privacy. Data on interaction was extracted from interviews and device logs. This paper contributes in knowledge on how physical design affects trust when interacting with a DA.

In the next section we describe related work in regards to the scope of this paper. This is followed by the design process and development of PIA, the study methodology used to collect data, and our findings. Lastly we will discuss and conclude on the findings of the study.

## 2 RELATED WORK

For a better understanding, topics related to this study were researched. These include; privacy concerns in IoT, general usage of DAs, and users trust in digital artifacts.

### Privacy Concerns in IoT

DAs are connected to the internet, and often to a network of other devices in households, thus creating an ecosystem of artifacts within that same household [18]. Therefore the concept of Internet of Things (IoT) gives cause to consider the privacy aspect of connecting everyday objects in a network [1]. A study by Lau et al. [16] delved into the reasons some users might give up aspects of their privacy for the functionality of a DA in their home. They found that convenience was the greatest motivator for the trade-off. Some users expressed resignation with the fact that their privacy was already compromised by existing artifacts [16]. In relation to this, Emami-Naeini et al. [7] found that the home was one of the most privacy-sensitive locations as opposed to public spaces were the collection of data was more acceptable. Debes et al. [5] found that microphones are perceived as one of the most violating sensors of privacy, only surpassed by video cameras. The privacy concern was increased in conjunction with the volume of information a sensor was able to collect. Thus placing them in the home is cause for concern.

Acceptance of IoT in the home is highly dependant on users trusting the organization behind the artifact, who has access to the data and how the collected data is used [35, 38]. Owners of these artifacts are in varying degrees accepting that organizations may use data to their own benefit [39]. The acceptance is caused by owners trusting the artifact. Or alternatively, as Riegelsberger et al. [28] argues, owners have trust in societal regulations (authorities and laws) to take action, if organizations are violating any rules that inflict danger or risk to their consumers.

### Usage of DAs

Physical DAs have the capabilities of: stream and control music services, get weather forecasts and news information, ask about factual questions, play games, control other smarthome artifacts, and set timers and alarms [16].

A study analyzed 376,000 commands and divided them into categories [29]. Here they found that music control were the most frequently used category accounting for 25%, controlling other smarthome devices were 14.7% and retrieving weather forecasts 4.6%. Interestingly it was also found that *misfire* (wake-word without a following command) and *command not transcribable* (background noise or low audio) accounted to more than 13%, which proves that voice controlled DA's are a challenging interaction modality. There are also challenges regarding audio's ephemeral attribute, because information received audibly is short-lived. This means audio is not ideal for presenting large amounts of information or navigating long lists [37].

Physical DAs are integrated into the home, usually being placed at a fixed spot, as opposed to smartphone DAs which you carry around. The placement of the artifact is often in a central location in the home, depending on most frequented rooms, proximity to other smart artifacts and the ability to be used from other rooms as well [16]. The location of the device might also pose concerns about trust and privacy. A central placement raises the amount of data the DA is able to collect, while placement in more private parts of the home such as the bedroom might pose concerns because of the types of data that can be collected. Researchers have explored this place-based attribute and found that the room placement does affect the usage of DAs. Having it placed in the kitchen or bedroom ended in few and very particular commands while having the speaker placed in the living room showed to have more open ended uses [16, 29].

### User Trust in Digital Artifacts

Just as humans, digital artifacts have attributes that induce trust. Fogg and Tseng [10] describe how the physical design, density and button detents can induce trust. They explain that trust extends much further and can both cover the artifact itself, but can also extend to surrounding factors. Such attributes were mapped out in the previously mentioned literature review [13]. The factors discovered in that literature review related to this paper are: *physical design*, *societal regulations*, *data handling*, *surrounding environment*, *attitude towards technology*, and *motivation* of the organization. These factors were selected because they were found interesting and particularly relevant in the context of this paper, where trust and privacy concerns are being studied.

## 3 DESIGN PROCESS AND IMPLEMENTATION

The purpose of this study is to affect trust and privacy by altering the physical design. Alternative design examples were explored, resulting in PIA. A prototype with similar functionality as a commercial physical DA.

### Provocation Prototypes

In a study by Milton et al., they created DA's for placement in a public park. The DAs created were in the form of animals seen in the park, which assisted in the placement designation. Therefore DAs in shapes of otters were placed near water, where users could expect to see actual otters [19]. This is an example of designing for user and environment expectations.

On the other side of this design spectrum, a design could be constructed to challenge the user's expectations and in some cases provoke users. Such as a study by Raptis et al., where provocative design was used to study everyday practices of electricity consumption [27]. In this case a box was created to inform users of their consumption of electricity by using the colors red and green to show if they could use their washing machine. Provocation was used in order to make participants reflect on their electricity consumption practices. In the same vein as the study by Raptis et al. [27], this paper will attempt to use provocation to inform users and make them reflect about their DA interaction.

### Physical Design

As this study sought to explore how physical design affects trust and privacy, the box containing the hardware received much attention. The researchers worked on the assumption that introducing a DA into one's home is based on a *taken-for-grantedness*, meaning that underlying problems of acquiring the device may be invisible to users [20]. As earlier stated, users of DAs accepts the risks of data being misused [39]. It is our intention to challenge this behavior by provocation [27]. Interaction design can be provocative in three dimensions: *conceptually*, *functionally* and *aesthetically* [2], where the latter is explored in this paper.

The majority of commercial physical DAs looks like a speaker, why they are often referred to as 'smart speakers' and can be confused with Bluetooth speakers as their look and size are similar. They are often equipped with soothing light in neutral colors that only light up during interaction. Their design can be described as elegant and minimalistic to make it fit with other ornaments in a household and blend in.
We attempt at provoking aesthetically by using the case of an old 'Blaupunkt Bari CR 7652' cassette recorder. This case was chosen as it had the appearance of a retro recording device, with a cassette being visible behind a transparent glass (figure 1d). This appearance compliments our intention of provoking aesthetically by evoking the recording functionality of DAs through the case's physical design. The design of the cassette recorder resembles recording devices portrayed in movies e.g. recording voice messages, interrogation of people, and surveillance of a household [11, 24, 31].

The case was originally intended to be in a horizontal position with dimensions W:286 x H:63 x D:233 mm (11.3 x 2.5 x 9.2 inch), having it 'lying down'. However, we chose to make it 'stand' in a vertical position (dimensions W:286 x H:233 x D:63 mm) to make PIA appear taller and make a larger surface visible when seen directly from the front and from different viewing angels from a distance. This position was chosen in an experimentation phase of positions and paper prototype attachments to represent the core functionalities of PIA.

The original buttons on the cassette recorder was kept in their respective placements on the top of the case (figure 1a and 1b). We chose to fix the original red recording button (figure 1a most right) in a 'pushed down' state. This reflects that the recording function of the case is always ON. It is the intent that this aesthetic element conveys the DA's functionality of always listening.

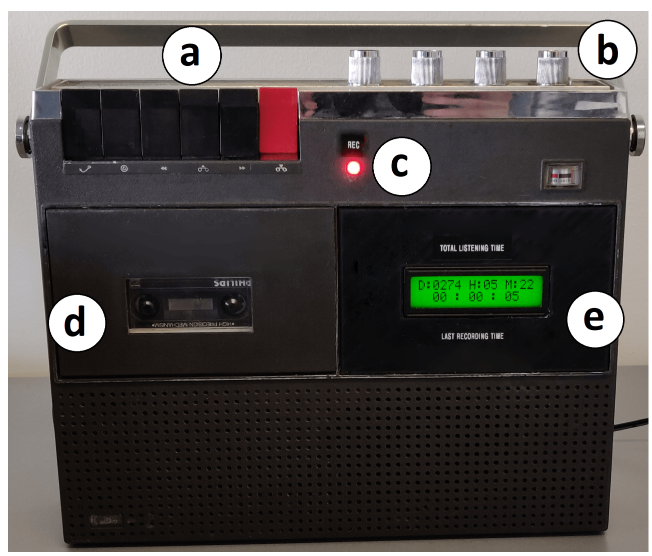


**Figure 1: PIA seen from the front: a) Original push buttons, b) Original turnable buttons, c) LED showing recording status, d) Cassette which plays when recording, e) LCD screen.**

The original cassette player mechanism was removed due to its large size. But as the cassette function is a main capability of this recorder, it was chosen to make a new moving mechanism. A servo engine was used to drive the cassette splines. The servo was coded in way so it produced sound similar to a standard recorder and moving in a pace as normal cassette tapes would do in a 'playing' state. This results in the cassette spinning around, but the actual recording on the tape is not applied, only mimicked. The tape is visible to the user (figure 1d), and they can see and hear the tape spin around, triggering a reference to analog recording. To amplify the recording reference, it was chosen to have the description of "Home recordings vol. 3" on the tape. The users were not able to remove the tape unless they opened the case's insides, as we had jammed the cassette holder from the inside, in order for them not to be able to play the tape and discover nothing was on it.

Different microphone designs were explored, with inspiration from decibel meters, sound studio microphones, phone recorders and surveillance equipment. Different design possibilities were discussed, with the main question being if the recording sensor should be visible or hidden. A large visible microphone is to resemble what we have seen in recording studios and decibel meters. However, we chose a more minimalist design closer to the original design of a commercial physical DA. This is also common in other devices such as telephone recorders and baby alarms, which we found not to have visible microphones, yet they still record sound.

In order to aesthetically emphasize the recording function of PIA, we chose to implement a 16x2 character LCD screen (figure 2). The upper line was used to display the total amount of time passed since turning ON a physical DA for the first time. We call this 'Total Listening Time' and is displayed in Days (D), Hours (H) and Minutes (M) (figure 2 top line). This draws on inspiration from cars which have a mileage counter starting from when the vehicle leaves the manufacture, always visible to the driver. It was also decided to add a line showing the length of the latest command interaction initiated by users. The inspiration came from sound recorders and dictaphone applications, which shows the length of recording in real-time. This was transferred to the LCD screen 'Last Recording Time' (figure 2 bottom line). In addition to the LCD screen, it was also chosen to include a red LED to provide simple status information [3] and visualize the recording functionality (figure 1c). This draws inspiration from video cameras and sound recording devices, where a red LED is most often used to show that the device is currently recording.

### Hardware

In order to fit our hardware inside the case the Blaupunkt recorder was stripped from most of its original internal components. Additionally some 3D printed parts were added to cover up the holes which became visible after this removal.

PIA consists of a Raspberry Pi 3 model B (figure 3e), a servo engine (figure 3c) that makes the cassette move, an LCD screen (figure 3b) to display the two times we described before. To record sound a USB-microphone (figure 3a) was used and an off-the-shelf small speaker was used to play sound (figure 3d). This was placed opposite to the microphone to make as much distance between the two components as possible and minimize the speaker's interference with the


**Figure 2: Closeup of the LCD screen on PIA. Top row displays the time since they first acquired a DA. Bottom row displays the duration of the last interaction**

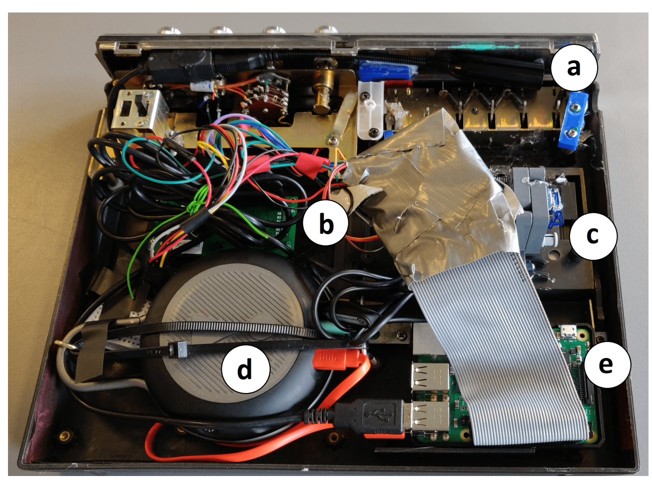


**Figure 3: Hardware components of PIA: a) USB-microphone, b) LCD screen, c) servo engine, d) speaker, e) Raspberry Pi.**

microphone. The speaker was chosen as it had similar specifications and sound quality to a Google Home Mini. We did not want to provide a worse sound quality experience than users of physical DAs are used to as this could affect their usage as well.

### Software

The Google Assistant was implemented using the Google Assistant Library (GAL) provided by Google. GAL is written in python and is used as the main file, communicating when to initiate the other hardware elements: the LED REC light, the servo to make the cassette rotate, and the screen to display the two counters. Lastly to see if and when the users turned OFF PIA, a script was made to log when the Raspberry Pi was turned ON. The scripts checked if the Pi was ON every five minutes. All scripts run as services meaning they start automatically when the Raspberry Pi is plugged in to power. This makes the Pi work similarly to a physical DA, which also starts up as soon as it is plugged into power.

## 4 STUDY METHODOLOGY

To see if physical design affects trust and privacy in DAs we engaged in a field study, in which the participants were to replace their physical DA with PIA. In the following subsections we will present details regarding our participants, the process of the study and the data we collected.

### Purpose

The purpose of the study is to see how changing the physical design of a DA affects user's trust and privacy. Since DAs blend into their surroundings [20], we sought to challenge this by making a DA that does not seamlessly blend into its surroundings and aesthetically demonstrate its recording functionality. It is our hypothesis that a DA that reflects its recording functionality more than consumer DAs, will make users reflect on their trust and privacy perceptions around DAs. This could lead to a change in their usage patterns and behavior around the DA as users are exposed to a more visible recording when interacting with PIA.

### Participants

Three households participated in the study, all living in, or close to, Aalborg, Denmark. They were recruited through our social network, and a public post on social media. They were chosen as they all had a Google Assistant-enabled device. Two households had acquired their DA fairly close in time, with household one (H1) on the 19th December and household two (H2) on the 25th December, both in 2018. Household three (H3) acquired their DA the 1st March 2019. The placements of the different households' DAs can be seen in figure 4 (left column).


**Figure 4: Images taken from the placements of the households' own DA and PIA.**

H1 comprised of a male and female being 31 and 29 years old. They also had two children being two and four years respectively. Both adults had full time jobs, with one working as a marketing assistant and the other as a carpenter. Their DA is placed in their living room in front of the TV, very centrally located in their household. The DA was connected with a Sonos speaker and a Chromecast.

H2 was a single male being 25 years old. They were a student in Aalborg and lived by himself. The DA is placed under the TV, which was placed in the main room of the apartment. They also had a connected Chromecast to the TV and Philips Hue lights to be voice controlled.

H3 was two male roommates. Both participants were 22 years old and were roommates in a small apartment. One of the participants have a job as an IT-supporter, and the other is on leave from university. They had their DA for the shortest amount of time, but had already acquired Phillips Hue for different rooms as well as other IoT devices. Their DA were centrally placed in their apartment on the kitchen table.

### Data Collection

Each of the households were asked to home PIA for one week. It were to substitute their own DA. The day we delivered PIA we helped them with the set-up to make sure everything worked properly. At the set-up we asked the participants to unplug their own DA and not use it. After the initial set-up the household members could decide the placement of PIA and they were allowed to move it or turn it OFF if they felt like it. We took a picture of the placement of their own DA before it was unplugged (figure 4 left column). Then we took a picture of the initial placement of PIA before we left (figure 4 right column). This way we could compare placements, and see if there were differences in how our participants placed their own DA, and how they placed PIA.

To compare the interaction we used log data from Google. These logs included the commands given to the DA, which we analyzed. The commands of the DAs were coded separately, from when they received it until substituting with PIA. Coding were based on the content categories of a quantitative study analyzing 278,654 commands to DAs [29].

Furthermore, we arranged an ending interview with each household where at least the primary participant of the study were present. We took a new picture of PIA's placement, to compare with its placement at the start of deployment. The end interview was based on their thoughts of having PIA in their home. We asked if they thought their usage pattern or interactions around the DA had changed, what they liked or disliked about it. They were also asked if they had changed their opinions on DAs, trust and privacy and if they, in the future, would change their behavior around and with DAs or other digital artifacts.

## 5 FINDINGS

The aim was to explore how the physical design of DAs affect users' trust and privacy. First findings from coding of log files are presented, and then findings from the qualitative interviews.

### Usage Pattern and Frequency

To analyze the frequency of use, logs from the households' DAs were retrieved. These are available for download from the Google Assistant API. The logs were analyzed before the households received PIA, by having two researchers code the logs individually. The results were then compared between the two researchers, discussing any differences until they came to an agreement. This was to insure more consistency in coding. Both the frequency of commands and which category each command belonged to was derived by coding the logs.

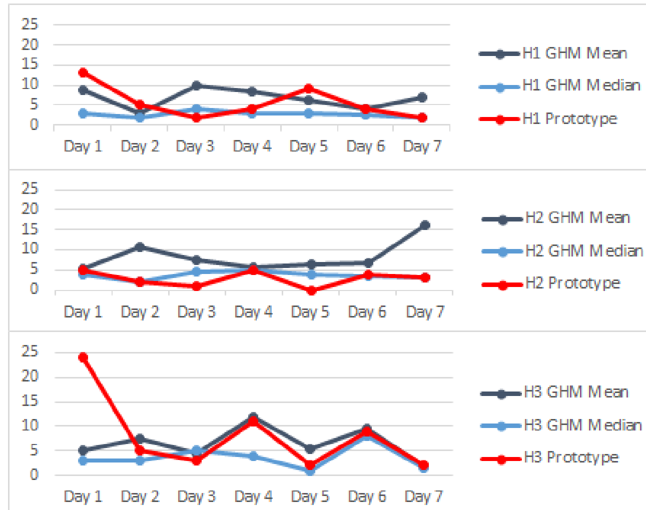


**Figure 5: A graph showing the three household's frequency of use for the duration of one week.**

The usage fluctuated with days of only one or two commands and other days peaking at 19 commands. This is when omitting the first week's 'experimentation phase' [29], which peaked at 61. Days with zero commands were omitted in frequency, as users cannot be affected by the physical design if they are not at home to interact with the DA. This was due to the possibility of our participants being on vacation or otherwise out of their house for one or several days.

Frequency graphs for each household, comparing the use of the household's own DA and PIA can be seen in figure 5. The dark blue and light blue line shows the mean and median usage of the participants' own DA as studied over a period of at least one month. The red line shows the usage of PIA during the 7-day week the evaluation lasted for each household.

Based on the three frequency charts, no noteworthy impact on the way the households use a DA, can be derived. While H1's frequency of use rose during deployment, H2's use fell. That H1's usage of PIA was a bit higher than their normal usage does correspond with a statement from their interviews where they said that they have used PIA more than they normally would their own. H1's increase could be caused by their curiosity, as their first day with PIA had

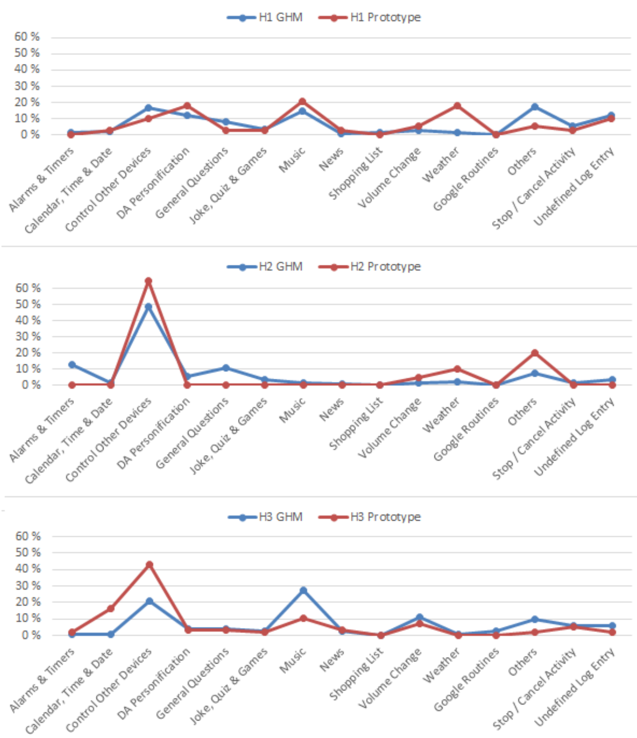


**Figure 6: A graph showing the distribution of command categories from the three households.**

more commands than their normal frequency of use. H2's frequency also correlates with their stated usage, since they did divulge that they did not use it much during the week of deployment. The frequency of H3 shows a significant spike during the first day of usage. This spike could be explained by an initial novelty use, where the fascination of the different physical design of PIA caused more use.

When looking at figure 5, the same pattern emerges when looking at different categories of use in figure 6. Usage of participants' own DAs and PIA are similar with minor deviations in certain categories. No major differences were identified in the data. H1 and H2 remarked that they used the *Weather* command often due to shifting weather conditions during the week of deployment. This can also be seen in figure 6 (top graph). This is confirmed by checking several weather forecasts services. The *Music* category in H3 shows a drop in usage, which can be attributed to the fact that H3 set-up a Chromecast device during deployment. This caused H3 to use their TV to play music instead of their speaker. This also caused a spike in *Control Other Devices* because control of the Chromecast fits in this category, thus resulting in a decrease in the *Music* category.

## Interview Findings

The end interviews conducted with the participants showed a change in their perception of DAs and did make them reflect more on their usage.

*DA Owners and Usage Patterns*

All of our participants describe themselves as *"early adopters"* or *"power users"* of technology, hence they are positive about using and acquiring new devices. An important factor is a user's *Attitude Towards Technology* which has a prevalent influence on their trust in said technology [13].

> *I believe I have quite a lot of technology in here* [the home]. *I have always been interested in technology, since I was a young child. But it is more for consumption and enjoyment than utility. It is not a must have to me, but just things I am appealed to [...] My first thought when acquiring the Mini* [Google Home mini] *was excitement, but also frightening. The element of having an active microphone in your home, which you do not really know when listens. (H2)*

In this quote H2 explains how they are curious to new technology, and although some of it frightens them, they still accept it. This correlates with findings of Lau et al. [16]. Furthermore H2 elaborated that at first, they were more conscious of the DA. However, as time went by it started to take less attention. This can be explained by the novelty of introducing a DA into one's home and is also seen in the frequency of use from the participants' logs. However, this novelty moves into more steady usage after the first week, which was also found by Sciuto et al. [29].

DAs are mostly used for their convenience as they allow for performing tasks hands free and always are available. H2 explained this as *"the thing of being lazy, where I use it* [Google Home Mini] *as a remote"*. However, they also stated that they did not use the Google Assistant on their smartphone before they acquired their physical DA. This is also the case for H3, as they also highly praise the possibility of being able to control music and smarthome artifacts, such as lights, as secondary interactions. It *"made things easier"* and *"you are able to multitask"* as you do not need to walk near a light switch, find the remote controller. You are able to keep working on your primary task as stated by H3.

In the household's logs, it can be seen that the most used categories of commands are *Control Other Devices* and *Music*. The DA is either being used as a voice controlled remote to other IoT devices or as a voice controlled music player. This is also confirmed by H2 and H3 in the above statements.

Another aspect to owning a DA is if you are to tell visitors that you have such a device placed in your home.

> *When your friends are visiting, they think it* [the DA] *is exciting. But I do not know, when they get into the home if they know that there is a risk they are being recorded. I do believe it is an area that needs to be more clearly stated. And the surveillance society in general. (H2)*

Sciuto et al. [29] found examples of household visitors either enjoying the DA playing games or having it perform rudimentary tasks. Others had experienced a visitor to request the device to be unplugged. This highlights one concern of owning a DA that is always listening. Are you supposed to inform visitors as they enter your home, as the visitors are somewhat interacting with a DA as soon as they are in hearing proximity of the device.

*Physical Design*

The physical design is an important aspect of this study, and was the focus for much of the interviews. H1 were very conscious of PIA and explained it was because of its much bigger size than that of commercial physical DAs. H1's perception of these DAs is that they are small and inconspicuous, which they point out as a negative element, because it is sometimes overlooked. They wished for the DA to be bigger. H3 state that their own DA blend in with its surroundings, and you easily forget it listens when having private conversations with other people. This correlates well with Dunne and Raby [6] who explains that technology have a risk of falling into everyday reality if it isn't "strange enough" or as Mogensen states, it becomes "invisible" [20]. H3 elaborated that the looks of their DA reminds of a normal speaker, its looks does not imply it is a Google Assistant having recording functionality. When referring to PIA H3 states *"I'm not fond of the design. I think it stands out to much and is too old school for me."*

During the discussion about PIA, H1 thought the design was somewhat *"spooky"*. When asked to elaborate, they singled out the *last recording time*, as being the thing that made it seem spooky, because it visualized how long they have been recorded. H2 had a similar experience with the screen. At first they did not understand what it visualized, but as they found out they stated *"It was intimidating because it shows how much data you are feeding the DA with."*. H3 concluded that it stood out very much from their other ornaments and technology. Again the screen was pointed out as the element taking the most attention.

An unforeseen effect the screen caused, was that H2 started measuring the efficiency of using a physical DA compared to turning light switches ON/OFF physically themselves and using the normal remote for the TV. They thought it was interesting to see if the DA actually was more efficient and convenient than performing the activities the regular way. This could be caused by the fact that H2 saw the DA as a voice-controlled remote, promoting convenience. They thought of it as a fun exercise to measure, but no matter the result they would still keep the DA due to its convenience. Even if they experienced it took longer, they would keep using the DA.

The cassette player had quite another effect than the screen, as participants found it interesting. H3 first thought of it as peculiar and *"out dated"*, but also mentioned it being *"cool"*. The sound also took attention, but overall H3 found the cassette player as a nice gimmick rather than something that affected their usage. In contrast the cassette player made H2 feel more under surveillance. When they heard or saw the cassette go around it *"made the recording feel more active"*, because they could relate this to when they were younger and recorded stuff on cassette tapes as well. It brought back memories and felt nostalgic. The cassette also made H2 think that we might record more than Google since the tape did not stop the second the LED light stopped but might run for an additional second. H2 says *"The way it works. It keeps recording. Something Happens."*. The cassette functionality shows a clear effect on H2 as they became more aware of PIAs recording functionality because of the cassette player sound.

All households pointed out the red REC LED as being a good feature because it visualized if the DA was active. It served as confirmation that PIA had heard the wake-word.

*Privacy and Trust*

It is apparent that users reflect about owning a DA and its workings of being an active microphone, before buying one. H3 explains:

> *It is showing trust to have an active Google Assistant in one's home because there is a chance it will listen all the time. Also when you have not talked to it. If there is no baseline of trust to the product or Google, or who ever has these* [DAs], *Amazon, Apple. If you do not have trust in it, it will be senseless to acquire one such device. (H3)*

Interviews with the households indicates that PIA achieved some provocation of the users, as they started to reflect more on trust and privacy. H1 expressed concern of how much information PIA recorded and saved during the study. They thought it saved as much as their own DA, as they were told, but said: *"[...] that was probably one giant lie."*.

This indicate a concern that PIA might be gathering more data than a commercial DA. H1 further elaborated that they were aware of PIA in their home, but it did not affect their normal conversations. Furthermore, none of the households mentioned that they turned OFF their physical DA or PIA, to avoid being recorded or unintentionally activate their DA while holding a private conversation. H2 mentioned that for them to take more action in this regard *"it would need some kind of scandal so that we all would wake up and take more responsibility."*. H3 speculates that a public scandal, which exposes a major organization for manipulating or mishandling users' information, could be what is needed for the public to take responsibility. H3 stated that having devices everywhere and always available is just the way the technology is heading. Although accepting it, H3 stated that we should still be cautious. Their reflections ended in considerations of having societal regulations that controlled the gathering of data:

> *I would prefer if there was some sort of control, for instance at a governmental level to control it, so that there were other instances overlooking them rather than them having free play [...] It would definitely be nice if there were some sort of controlling regulations who looked trough the data* [the DAs are collecting] [...] *it is unrealistic, but it would be the most ideal that all data they* [organizations] *gather are screened before the organization gets the data. (H3)*

These reflections are in conjunction with the trust factor *Social Regulations* we have extracted in our literature review of factors affecting trust [13]. This is based on findings from Riegelsberger et al. [28], who in their framework state that users are to put trust in governmental agencies to protect consumers' interests.

When asked about the worst aspects of having a DA in their home, H1 responded that they feared their data getting into the wrong hands. They further elaborated that they didn't believe Google to be the right hands, but they preferred them to others: *"Who else would it be? It* [the data] *should not be in anyone's hands, preferably."* H2 had similar fears, explaining that they feared that the data they give the DA can be used against them if they were to be leaked. They thought the idea of having an assistant, *"a helper"*, that you are afraid to be turned against you is wrong. H1 went further and explained that in order to prevent their data from being in anyone's hands they would need to not use any technology connected to the internet. But they were not willing to make that change in their life. H3 had similar thoughts, as they claim to know about Google exploiting data, and that it is impossible to avoid as other artifacts or services also will be used to collect data. *Data Handling* as a trust factor [13] comes to light in these quotes about Google's gathering, and storing of users' data. In the case of H3 they remarked that they have concerns about their data getting exposed, but Google was thought of as *"not the worst hands"* to handle their data.

> *Google are known to spy on people and their whereabouts using their services. I do not mind it that much, because they will listen anyway if we talk privacy. There is a chance they will get data else where if a Google service is involved [...] If you have any piece of technology, if it is a PC, smart speaker, maybe even a* [smart] *fridge. There is always something under the ropes that listens. Either it is directly or, what is it called, indirectly. (H3)*

The acceptance of this perceived misuse, can be explained by another trust factor, *Motivation*, which describes an organization's underlying reasons and motivations to perform certain activities, e.g. corporate social responsibility, charity donations, and storing users' data securely to maintain a good reputation [13].

The users' unwillingness to forego the functionality and convenience of a DA in spite of their fears, correlates with the usage patterns seen in figure 5 and figure 6. Their usage did not change in frequency during the deployment even with the added emphasis on the recording functionality in the physical design. This points to it being much harder to change the users practices than anticipated. This can maybe be explained in a quote from H3 stating: [...] *'Google collect all that information about you. It is not all people that is used for something conspicuous*". Referring that they will not stand out in the masses of users of DAs as they are behaving normally. The recording and storing of the massive amounts of data from all DA users did not worry the participants as it will only be used against people doing unlawful or harmful activities. These findings correlate with the findings of other studies where users of IoT are more inclined to forgo privacy concerns in exchange for convenience [12, 39].

## 6 DISCUSSION

### Privacy and Convenience

Provoking the households had limited results when referring to their daily usage patterns, as seen in figure 5 and figure 6. In the interviews all households stated that they were affected by the changes in the physical design. The screen was mentioned as an element that did evoke negative feelings of being recorded and made users more aware of this functionality. However, this did not seem to transfer to the actual use, seen in the logs. This relates to the findings of Lau et al. [16] and Hsu and Lin [12], where users of IoT are more concerned about convenience of technology than privacy invasion. The participants in our study all expressed concern about privacy, and protection of data in various degrees. However, they also expressed a sense of giving-up towards limiting data collection from organizations since they all do it to some degree. Both established research [12, 16, 39] and our findings point to loss of privacy and data protection is seen as a necessary compromise in using digital artifacts.

### Provoking Users

Our findings suggest that the design of PIA might not have been provocative enough. According to Mogensen this would make the artifact blend into everyday life [20]. It was decided against a more provocative design, since an artifact can also be too provocative resulting in users dismissing the artifact completely [6].

It was considered to use more provocation in the *aesthetic* dimension [2] of PIA by both visualizing the recording functionality more, and implementing a visual microphone. Different microphones were considered including a robotic microphone, which would follow the sound. Another suggestion were to implement a volume-unit meter reacting to the sound volume in the room, and visualize the level through lights or a display.

The design could also be made more provocative using the *functional* dimension. Here it was considered to have the microphone resemble a camera as it is a common symbol for surveillance. This was however decided against in the development phase, as findings of Debes et al. [5] found that the richness of the sensor and data collected, affects the privacy perception. The richer data a sensor is able to gather, the more privacy invasive it is perceived. During development we were concerned that the richness of a camera would be too provocative, because it would extend the functionality of our participants' DAs, as they only make use of sound.

For the remaining provocative dimension, *conceptual*, we refrained from altering this as the concept of a DA is believed to be too drastic of a change. Our scope sought to only explore the physical design and how this affects trust and privacy.

### Limitations

It was only possible to have each household home PIA for one week of evaluation. This is a very limited duration and may not be adequate for the purpose of this study. It was established by another study, that the first week of owning a DA causes a novelty effect with very different usage patterns than the steady use in the following weeks [29]. However, since the functionality of PIA and their own DA is similar, the novelty effect were thooght not to be a major factor since the participants would not be interacting with an entirely new technology. Looking at the frequency charts for deployment of PIA, some higher usages were seen in the first day. It could be argued that some novelty effect took place. Extending the duration of the evaluation could affect the usage pattern more over time.

The duration of one week could also affect placement of PIA, as all households chose to leave it in the same placement as they initially chose during set-up. This decision could however also be due to the size of PIA, as it is larger than their own DA, thus can not be placed in the same location if the location is small or filled with other ornaments.

## 7 CONCLUSION

For this study our intent was to find if altering the physical design of physical DAs would change users' trust and affect their view on privacy.

Our findings show that users can be affected in regards to trust and privacy by changing the physical design of an artifact which they currently own. Every household mentioned that they felt more surveilled. The physical design and sounds PIA produced woke feelings of being spooky and scary. However, although the household participants had increased their feeling of being recorded, it did not show in their actual usage in their logs. Their distribution of command categories remained similar to their own DA. Each of them also commented that although they felt more surveilled, they did not actually feel they changed they behavior with or around PIA. Thus it can be concluded that PIA were successful in provoking the participants, and make them reflect more about convenience and privacy, however whether it is possible to change users' behavior around DAs through provocation can not be determined by our findings and will need further research.

Further research on trust and privacy in DAs could attempt to elevate the provocation level further compared to PIA. Either by using the suggestions we come up with in the discussion section or come up with alternatives. Another study could also attempt to provoke in the same manner with other digital artifacts to see if the same pattern can be found for other devices.

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## REFERENCES


[1] Luigi Atzori, Antonio Iera, and Giacomo Morabito. 2010. The Internet of Things: A survey. *Computer Networks* 54, 15 (2010), 2787 – 2805. https://doi.org/10.1016/j.comnet.2010.05.010

[2] Shaowen Bardzell, Jeffrey Bardzell, Jodi Forlizzi, John Zimmerman, and John Antanitis. 2012. Critical Design and Critical Theory: The Challenge of Designing for Provocation. In *Proceedings of the Designing Interactive Systems Conference (DIS '12)*. ACM, New York, NY, USA, 288–297. https://doi.org/10.1145/2317956.2318001

[3] David Benyon. 2010. *Designing interactive systems: a comprehensive guide to HCI, UX and interaction design* (second ed.). Pearson Education Limited. 604 pages. www.pearson-books.com//katalog.bibl.liu.se/uhtbin/cgisirsi.exe/?ps=sbpFbSYth5/VALLA/136370064/9

[4] Scott Carey. 2018. Does Amazon Alexa or Google Home listen to my conversations? Online article; posted 25-May-2018; https://www.techworld.com/security/does-amazon-alexa-listen-to-my-conversations-3661967/.

[5] Christian Debes, Andreas Merentitis, Sergey Sukhanov, Maria Niessen, Nikolaos Frangiadakis, and Alexander Bauer. 2016. Monitoring Activities of Daily Living in Smart Homes: Understanding human behavior. *IEEE Signal Processing Magazine* 33 (03 2016), 81–94. https://doi.org/10.1109/MSP.2015.2503881

[6] Anthony Dunne and Fiona Raby. 2001. *Design noir: The secret life of electronic objects.* Springer Science & Business Media.

[7] Pardis Emami-Naeini, Sruti Bhagavatula, Hana Habib, Martin Degeling, Lujo Bauer, Lorrie Faith Cranor, and Norman Sadeh. 2017. Privacy Expectations and Preferences in an IoT World. In *Proceedings of the Thirteenth USENIX Conference on Usable Privacy and Security (SOUPS'17)*. USENIX Association, Berkeley, CA, USA, 399–412. http://dl.acm.org/citation.cfm?id=3235924.3235956

[8] Darrell Etherington. 2014. Amazon Echo Is A $199 Connected Speaker Packing An Always-On Siri-Style Assistant. Online article; posted 02-February-2014; https://techcrunch.com/2014/11/06/amazon-echo/?guccounter=1.

[9] Michael Fischer, Giovanni Campagna, Silei Xu, and Monica S. Lam. 2018. Brassau: Automatic Generation of Graphical User Interfaces for Virtual Assistants. In *Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '18)*. ACM, New York, NY, USA, Article 33, 12 pages. https://doi.org/10.1145/3229434.3229481

[10] B. J. Fogg and Hsiang Tseng. 1999. The Elements of Computer Credibility. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '99)*. ACM, New York, NY, USA, 80–87. https://doi.org/10.1145/302979.303001

[11] F. Henckel von Donnersmarck (Producer & director). 2006. Das Leben der Anderen. United States: Buena Vista Distribution.

[12] Chin-Lung Hsu and Judy Chuan-Chuan Lin. 2016. An empirical examination of consumer adoption of Internet of Things services: Network externalities and concern for information privacy perspectives. *Computers in Human Behavior* 62 (2016), 516 – 527. https://doi.org/10.1016/j.chb.2016.04.023

[13] Jesper Quist Jensen, Kathrine Theilmann Gregersen, Kenneth Uldbjerg Jørgensen, and Rasmus Thygesen Larsen. 2019. Trust in Digital Assistants - A Literature Review. (2019). University Project.

[14] Milton Keynes. 2019. Strategy Analytics: 2018 Global Smart Speaker Sales Reached 86.2 Million Units on Back of Record Q4. Online article; posted 02-February-2019; https://news.strategyanalytics.com/press-release/devices/strategy-analytics-2018-global-smart-speaker-sales-reached-862-million-units.

[15] Seyeong Kim, Yea-kyung Row, and Tek-Jin Nam. 2018. Thermal Interaction with a Voice-based Intelligent Agent. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems (CHI EA '18)*. ACM, New York, NY, USA, Article LBW631, 6 pages. https://doi.org/10.1145/3170427.3188656

[16] Josephine Lau, Benjamin Zimmerman, and Florian Schaub. 2018. Alexa, Are You Listening?: Privacy Perceptions, Concerns and Privacy-seeking Behaviors with Smart Speakers. *Proc. ACM Hum.-Comput. Interact.* 2, CSCW, Article 102 (Nov. 2018), 31 pages. https://doi.org/10.1145/3274371

[17] Kif Leswing. 2019. Amazon accidentally sent 1,700 Alexa recordings to the wrong person, including audio from in the shower. Online article; posted 20-December-2018; https://www.businessinsider.com/amazon-sends-alexa-shower-recordings-to-wrong-person-2018-12?r=USIR=T.

[18] M. Levin. 2014. *Designing Multi-Device Experiences: An Ecosystem Approach to User Experiences across Devices.* O'Reilly Media. https://books.google.dk/books?id=LfrYAgAAQBAJ

[19] R. Milton, D. Hay, S. Gray, B. Buyuklieva, and A. Hudson-Smith. 2018. Smart IoT and Soft AI. In *Living in the Internet of Things: Cybersecurity of the IoT - 2018*. 1–6. https://doi.org/10.1049/cp.2018.0016

[20] Preben Mogensen. 1992. Towards a Provotyping Approach in Systems Development. *Scandinavian J. Inf. Systems* 4, 1 (1992), 5.

[21] Aarthi Easwara Moorthy and Kim-Phuong L. Vu. 2015. Privacy Concerns for Use of Voice Activated Personal Assistant in the Public Space. *International Journal of Human-Computer Interaction* 31, 4 (2015), 307–335. https://doi.org/10.1080/10447318.2014.986642

[22] Christine Murad, Cosmin Munteanu, Leigh Clark, and Benjamin R. Cowan. 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 (MobileHCI '18)*. ACM, New York, NY, USA, 269–276. https://doi.org/10.1145/3236112.3236149

[23] Quynh N. Nguyen, Anh Ta, and Victor Prybutok. 2018. An Integrated Model of Voice-User Interface Continuance Intention: The Gender Effect. *International Journal of Human-Computer Interaction* 0, 0 (2018), 1–16. https://doi.org/10.1080/10447318.2018.1525023

[24] N. Park, T Bevan, E. Fellner (Producers), and E. Wright (Director). 2017. Baby Driver. United States: Sony Pictures.

[25] Martin Porcheron, Joel E. Fischer, Stuart Reeves, and Sarah Sharples. 2018. Voice Interfaces in Everyday Life. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. ACM, New York, NY, USA, Article 640, 12 pages. https://doi.org/10.1145/3173574.3174214

[26] Martin Porcheron, Joel E. Fischer, and Sarah Sharples. 2017. "Do Animals Have Accents?": Talking with Agents in Multi-Party Conversation. In *Proceedings of the 2017 ACM Conference on Computer Supported Cooperative Work and Social Computing (CSCW '17)*. ACM, New York, NY, USA, 207–219. https://doi.org/10.1145/2998181.2998298

[27] Dimitrios Raptis, Rikke Hagensby Jensen, Jesper Kjeldskov, and Mikael B. Skov. 2017. Aesthetic, Functional and Conceptual Provocation in Research Through Design. In *Proceedings of the 2017 Conference on Designing Interactive Systems (DIS '17)*. ACM, New York, NY, USA, 29–41. https://doi.org/10.1145/3064663.3064739

[28] Jens Riegelsberger, M. Angela Sasse, and John D. McCarthy. 2005. The Mechanics of Trust: A Framework for Research and Design. *Int. J. Hum.-Comput. Stud.* 62, 3 (March 2005), 381–422. https://doi.org/10.1016/j.ijhcs.2005.01.001

[29] Alex Sciuto, Arnita Saini, Jodi Forlizzi, and Jason I. Hong. 2018. "Hey Alexa, What's Up?": A Mixed-Methods Studies of In-Home Conversational Agent Usage. In *Proceedings of the 2018 Designing Interactive Systems Conference (DIS '18)*. ACM, New York, NY, USA, 857–868. https://doi.org/10.1145/3196709.3196772

[30] Ameneh Shamekhi, Q. Vera Liao, Dakuo Wang, Rachel K. E. Bellamy, and Thomas Erickson. 2018. Face Value? Exploring the Effects of Embodiment for a Group Facilitation Agent. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. ACM, New York, NY, USA, Article 391, 13 pages. https://doi.org/10.1145/3173574.3173965

[31] J. Sistrom (Producer) and B. Wilder (Director). 1944. Double Indemnity.

[32] Chris Smith. 2017. Google Home Mini caught recording everything and sending all the data to Google. Online article; posted 11-October-2017; https://bgr.com/2017/10/11/google-home-mini-spying-on-user-fix/.

[33] Chris Stokel-Walker. 2018. Will you be getting a smart home spy for Christmas? Online article; posted 10-November-2018; https://www.theguardian.com/technology/2018/nov/10/spy-christmas-smart-home-facebook-portal-google-home-hub-amazon-show-alexa.

[34] Sam Wolfson. 2018. Amazon's Alexa recorded private conversation and sent it to random contact. Online article; posted 24-May-2019; https://www.theguardian.com/technology/2018/may/24/amazon-alexa-recorded-conversation.

[35] Peter Worthy, Ben Matthews, and Stephen Viller. 2016. Trust Me: Doubts and Concerns Living with the Internet of Things. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems (DIS '16)*. ACM, New York, NY, USA, 427–434. https://doi.org/10.1145/2901790.2901890

[36] Linda Wulf, Markus Garschall, Julia Himmelsbach, and Manfred Tscheligi. 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 (NordiCHI '14)*. ACM, New York, NY, USA, 203–206. https://doi.org/10.1145/2639189.2639251

[37] Nicole Yankelovich. 1996. How Do Users Know What to Say? *interactions* 3, 6 (Dec. 1996), 32–43. https://doi.org/10.1145/242485.242500

[38] Eric Zeng, Shrirang Mare, and Franziska Roesner. 2017. End User Security & Privacy Concerns with Smart Homes. In *Proceedings of the Thirteenth USENIX Conference on Usable Privacy and Security (SOUPS'17)*. USENIX Association, Berkeley, CA, USA, 65–80. http://dl.acm.org/citation.cfm?id=3235924.3235931

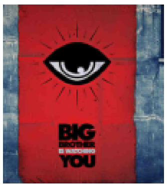
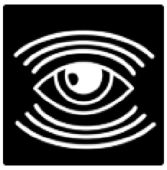
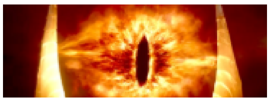
[39] Serena Zheng, Noah Apthorpe, Marshini Chetty, and Nick Feamster. 2018. User Perceptions of Smart Home IoT Privacy. *Proc. ACM Hum.-Comput. Interact.* 2, CSCW, Article 200 (Nov. 2018), 20 pages. https://doi.org/10.1145/3274469

# Appendices

## Appendix 1: Designing PIA

### 1.1 Inspiration

The design of PIA started out by gathering inspiration. This involved searching for inspiration in movies, TV-series, art and other sources with surveillance and privacy as major themes, This resulted in a multitude of pictures which were described in an inspiration table (seen below). The table focuses on three design elements, *visual*, *sound* and *movement* which could be used in the design of our prototype. The table then served as a basis for sketching of the prototype.

| Image | Visual | Sound | Movement |
|---|---|---|---|
|   | Eyes used as a common symbol of surveillance. many cameras look like eyes. | | the eyeball can move around |
|  | Eye incorporated in the case of a security camera | | |
|  | The eye of Sauron is always watching | | Moves to detect objects or people |

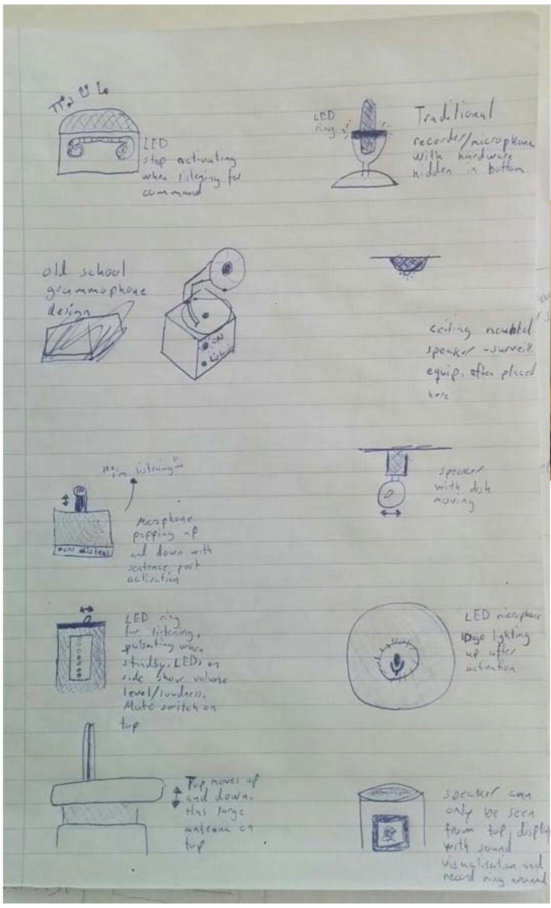
## 1.2 Sketching

The sketching and design of PIA happened over several iterations. The first general ideas were meant to narrow down major design suggestions (as exemplified on the left picture below). These first suggestions revolved around the overall shape of the DA prototype. Suggestions on this included things such as: a large recorder, a movable camera, and other sketches that originated from the inspiration images.

The sketches were narrowed down, and the design of a vintage tape recorder were chosen. From here it was a matter of accessibility, and what we could get of vintage recorders on the market.

After a suitable recorder was found, a new series of sketches were created. These sketches focused on functionality, and took inspiration from the design elements in the inspiration table from the previous page.

The sketches were placed on the recorder as to illustrate functionality and placement to discuss the ideas further (as exemplified on the right picture below). Through this process the prototype's design was decided through several iterations resulting in PIA.




# Appendix 2: Prototype software development

The main functionality used for PIA in this project came from the Google assistant SDK, utilizing the Google Assistant Library (GAL) [8]. This script contained a turnkey solution for quick integration of the Google Assistant (GA) software within prototyping hardware boards such as a Raspberry Pi, which was the case for this project. This appendix aims to describe and elaborate on the scripts, custom development, and coding used in the creation of PIA.

The code runs in four separate scripts. Three of the scripts controls PIA's functionality and one script runs separately to log when the Raspberry is turned ON. One of the scripts for functionality is called *hotword.py* and is part of GAL. The Two other scripts we made ourselves is called *runScreen.py* and *runServo.py*. The scripts make use of a python file called *daFunctions.py*, that holds custom made functions for calculating time and saving files, to reduce repetition of code and make it more simple. Lastly the separate script called *saveTime.py* continuously saves the date and time in a file of when the Raspberry Pi is ON, to let us see if it has been turned OFF.

All four scripts runs as services on the Raspberry Pi. This enables them to run a start-up and also makes it easier to troubleshoot problems since the output from the services are logged.

## 2.1 Hotword Script

The main script in GAL is a script named hotword.py. All PIA's functionality runs through this script, which make it possible to make and control custom functionality. The script works on if-statements that run on different event types. We utilise four of these event types:

- EventType.ON_START_FINISHED (when the script starts and GA is ready to be activated).
- EventType.ON_CONVERSATION_TURN_STARTED (when GA is activated and listens for command).
- EventType.ON_CONVERSATION_TURN_TIMEOUT (When no command is detected after GA is activated).
- EventType.ON_CONVERSATION_TURN_FINISHED (When a command has been processed and there is no follow up).

These events are used to initiate custom functionality. The light is controlled from this script by turning it ON in ON_CONVERSATION_TURN_STARTED and turning OFF in ON_CONVERSATION_TURN_FINISHED. The other hardware is controlled by saving three different files with pickle [9] for the other scripts to read.

- onState.pickle - either a '0' or '1' to show if the GA is active.
- dblConv.pickle - either a '0' or '1' to show if the command has a follow up command.
- currentTime.pickle - saves the time of GA activation in a datetime object.

All three files are updated in ON_CONVERSATION_TURN_STARTED to show that the GA is active.

## 2.2 Servo Script

The runServo script continuously read onState.pickle every second to see if the GA is active. If the file contains a '1' the servo rotates the tape forwards and backwards until a '0' is read from the file, hence the GA is inactive.

## 2.3 Screen Script

For controlling the screen the adafruit_character_lcd library [7] from Adafruit is used. The library enables us to print a string to the 16x2 character LCD screen. For calculating the times for the screen the datetime module [10] of python is used. This was achieved by subtracting a start time from the current time and then using the *total_seconds()* method to get the occured time in seconds to save in a variable. This variable is then run through one of our own functions called *timeConv()*, which converts the seconds to days, hours, minutes and seconds and returns a list-item with these values. The list is then used to make a string to each of the two lines for the LCD screen.

To print the top line of the screen (Total Listening Time) the date and time for when the household first turned on their DA is saved in a datetime object which then goes through the aforementioned steps to output a 'Total Listening Time'. The screen is updated once a second.

For the bottom line of the LCD screen (Last Recording Time) the onState.pickle files is continuously read every second to see if the GA is active. If the onState.pickle is '1' then dblConv.pickle is read to see if the command is a follow-up command or not. If dblConv.pickle is '0' the currentTime.pickle file (also updated in hotword.py on activation) is read to get the time of activation. This is done to avoid the time of 'Last Recording Time' being reset on follow-up commands.
The datetime object acquired through this process is then used as described above to calculate the 'Last Recording Time' which is then saved in a string. This string is then added to the screen which is updated once a second. When the GA is inactive only the top line of the screen is updated.

## 2.4 Save Time Script

The SaveTime script is started as a service when the Raspberry Pi starts. It prints a line with "start" and the current time the first time the loop runs. After this it continues printing a line with the current time every five minutes. This was implemented as a way of seeing if the participants of the study, turned OFF the prototype at any point during deployment.

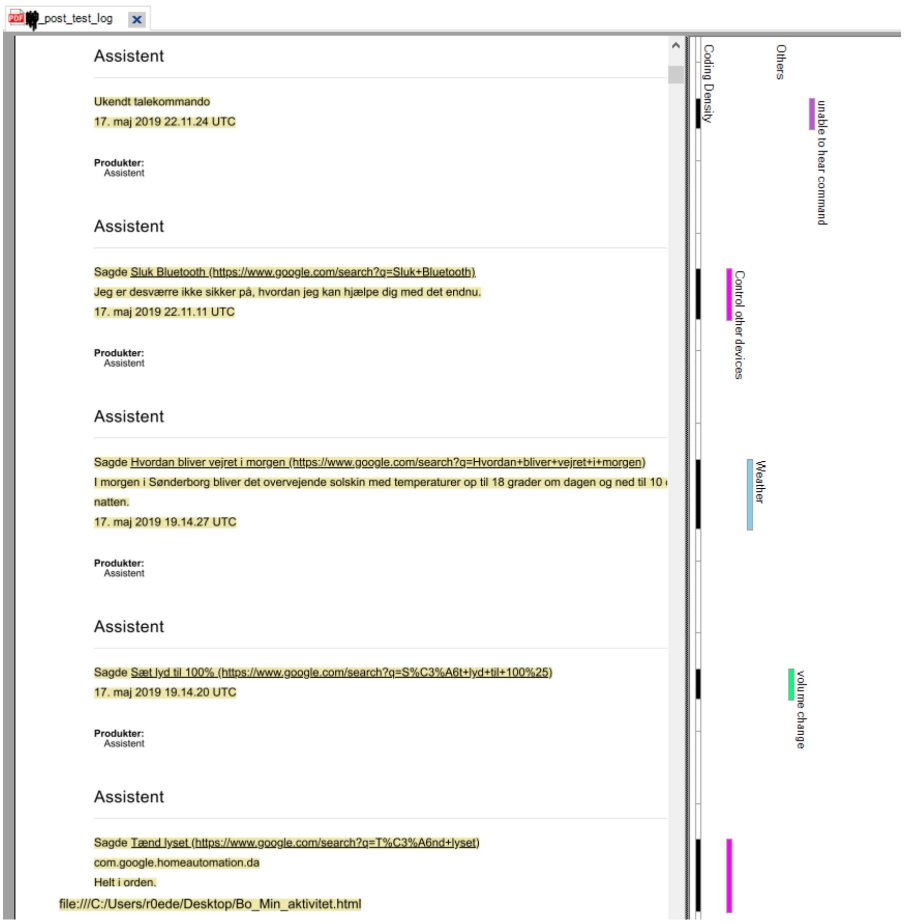
## Appendix 3: Coding of Logs from Google Assistant API

To analyze the log data from our participants we made use of Nvivo 12 to code the documents. The Google Assistant API makes it possible to download a log file for your user and see your various activities with Google services, specifictly also for your assistant usage. The three participants were asked to download their log files for their digital assistant, which we converted into a PDF document to make it possible for NVivo to open the documents. The codes were based on categories from another paper [5], which was extracted from 278,654 commands. Some of the codes were then combined and renamed to better fit the scope of our research resulting in 15 categories. This included a category called *Others* for log entries that we were not able to interpret the meaning of, based on the output from the logs.

Each log were analyzed by two researchers coding the commands individually in NVivo (Screenshot seen in figure below). Codes were made based on the users intention to do an action, meaning that in cases were it was obvious that multiple consecutive log entries were attempts at a single action these were coded as one instance of the category. This is because the main scope of this paper is to explore the users' purpose of using a DA, rather than its usability.

When the researchers had finished their coding, they sat together and compared each node. Either they agreed on the categorisation of the command or they would discuss it to make consistency in how each of the categories were applied to the commands. In total we had 1.502 codes for all of the three participants.

**Code Categories:**
Alarms & Timers
Calendar, Time & Date
Control Other Devices
DA Personification
General Questions
Joke, Quiz & Games
Music
News
Shopping List
Volume Change
Weather
Google Routines
Others
Stop / Cancel Activity
Undefined Log Entry



# Appendix 4: Interview Guides

## 4.1 Initial Interview: Before Homing Prototype

These questions were created with the intent of understanding the participants which had agreed to participate in the study. The interviews took place before deployment of PIA. The interview also had the purpose of gaining knowledge of the personalization the users had added to their own DA. Personalization such as language, voice, and activation sound. These personalizations were used to individually customize PIA to their own DA settings.

Why do you have a Google home?

What do you use your Google Home for?

- Give good and bad examples / stories with the use
- Who else is the household uses the device? - Do they have the same experiences?

Where is your Google Home located?

- Why is it located here? Central placement / anonymous placement ??

What would you say is Google Home's primary feature?

- Listen or playing

How do you feel about Google Home is listening for a wake word all the time?

- (It's a microphone that constantly listens)

Do you ever use the mute button?

- When? Why?

What do you think happens with the commands you use?

- Do you think it saves everything it hears? - How long does it take?

What do you think Google is using your data for?

Do you trust Google to handle the data correctly?

*Do you know that Google have a log function that stores the commands you have used?*
*Can we have it sent to our survey?*

## 4.2 End Interview: After Prototype home study

This interview guide were used when visiting the participants prior to deployment of PIA. The left column of the table below shows an abstract question we did not ask the participants, but was used as baseline to create the questions in the column to the right. The questions in the right column were asked to find information about our participants, as well as their usage.

<table>
<tr><td rowspan="6">Who are the general Google Home user?</td><td>How has the week generally gone by with our device?</td></tr>
<tr><td>What do you think of when thinking of privacy and technology?</td></tr>
<tr><td>What do you think of when thinking of trust and privacy</td></tr>
<tr><td>What is you general opinion about IT and technology in general?<br>- (early adopter,enthusiast, skeptical, negative)<br>- How much technology do you have in your home?<br>- Has it always been the same or has your opinion changed?<br>    - what made it change</td></tr>
<tr><td>What were your first thoughts when you got hands on your smart speaker?</td></tr>
<tr><td>What is the best thing about owning af smart speaker in your home?</td></tr>
<tr><td rowspan="4">Why do people use a DA, and what activities is it used for?</td><td>What activities are you using your smart speaker for?<br>- please provide concrete examples</td></tr>
<tr><td>Are there functions which you have first started to use when you acquired the smart speaker? - which, why</td></tr>
<tr><td>Are there functions which you refuse to use, but you know the smart speaker is capable of? - which, why</td></tr>
<tr><td>How many times a day do you estimate you use your smart speaker?</td></tr>
</table>

| | |
|---|---|
| | Have you experienced that your smart speaker have unexpectedly started to listen for a command without you (or other household members) using the wake word? |
| | Have you experienced that your smart speaker have trouble hearing or understanding your commands? |
| | Which commands have you used the most for the duration you had our device? |
| | How many times a day would you estimate you have used our device? |
| **How does it affect users behaviour to have Google Home in their home?** | How conscious are you of its presence? |
| | Have the smart speaker always been placed at the same spot since you acquired it? - have you moved it, why? |
| | Are you more aware of your activities and conversations when you are around a smart speaker? |
| | How conscious how you been of our device?<br>- have there been any changes in your activities or conversations with our device |
| | How much do you think our device is saving of data? |
| | Have you placed our device in other spots than the initial placement when it was set up?<br>- why |
| | Have you changed your looks on smart speakers by homing our device?<br>- what about you general opinion about IT and technology |
| **How does the physical design of digital assistants have an** | What do you think of the design of smart speakers?<br>- does the look compliment its functionality? |
| | What do you think of the design of our device? |

| | |
|---|---|
| **effect on privacy and trust?** | - What elements do you like? Don't like?<br>- Which elements do you think contribute most to the functionality of recording - how, why |
| | If you could any changes to the device, what would it be? |
| **What challenges are there in using digital assistants?** | What is the worst thing you can think of could happen when homing a smart speaker? |
| | What is the most negative of owning a smart speaker? |
| | Are you afraid that your data might be misused or fall into the wrong hands? |

# Appendix References


1. Shaowen Bardzell, Jeffrey Bardzell, Jodi Forlizzi, John Zimmerman, and Jo Antanitis. 2012. Critical Design and Critical Theory: The Challenge of Designing for Provocation. In Proceedings of the Designing Interactive Systems Conference (DIS ’12). ACM, New York, NY, USA, 288–297. https://doi.org/10.1145/2317956.2318001

2. Jesper Quist Jensen, Kathrine Theilmann Gregersen, Kenneth Uldbjerg Jørgensen, and Rasmus Thygesen Larsen. 2019. Trust in Digital Assistants - A Literature Review. (2019). University Project.

3. Milton Keynes. 2019. Strategy Analytics: 2018 Global Smart Speaker Sales Reached 86.2 Million Units on Back of Record Q4. Online; posted 02-February-2019; https://news.strategyanalytics.com/pressrelease/devices/strategy-analytics-2018-global-smart-speaker-salesreached-862-million-units

4. Preben Mogensen. 1992. Towards a Provotyping Approach in Systems Development. Scandinavian J. Inf. Systems 4, 1 (1992), 5.

5. Alex Sciuto, Arnita Saini, Jodi Forlizzi, and Jason I. Hong. 2018. "Hey Alexa, What’s Up?": A Mixed-Methods Studies of In-Home Conversational Agent Usage. In Proceedings of the 2018 Designing Interactive Systems Conference (DIS ’18). ACM, New York, NY, USA, 857–868. https://doi.org/10.1145/3196709.3196772

6. Sam Wolfson. 2018. Amazon’s Alexa recorded private conversation and sent it to random contact. Online article; posted 24-May-2019; https://www.theguardian.com/technology/2018/may/24/amazon-alexa-recorded-conversation

7. learn.adafruit.com - Character LCDs - Python & CircuitPython. Online; Last visited 2019, Juni 03; Retrieved from https://learn.adafruit.com/character-lcds/python-circuitpython

8. Google Developers - Google Assistant SDK. Online; Last visited 2019, May 30; Retrieved from https://developers.google.com/assistant/sdk/guides/library/python/

9. python.org - 11.1. pickle - Python object serialization. Online; Last visited 2019, Juni 03; Retrieved from https://docs.python.org/2/library/pickle.html

10. python.org - 8.1. datetime - Basic date and time types. Online; Last visited 2019, Juni 03; Retrieved from https://docs.python.org/2/library/datetime.html