# Siri, Alexa, Cortana, and Google Assistant: Are you Eavesdropping?

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## ABSTRACT

An IVA or Intelligent Virtual Assistant is a software that is capable of answering questions or completing tasks given by the user. The user's devices undertakes a comprehensive process of linking the hardware to the voice assistant's server. Within the server, there is computation in deep neural networks to "understand" if the voice assistant is being called into action or what is being asked of the IVA.

The linking procedure between the hardware and the server has changed significantly over time as privacy concerns and consumer right have become a contested debating point. For example, for many IVA companies, third party sources can no longer process or parse speech into the deep neural network. In turn, the user's data is not explicitly exposed to external data breeches. The data is considered to be more secure within in company. Each IVA has a different level of aptitude, communication, encryption, security, and storage of information.

Although third party sources are no longer used to interpret speech, technology companies have not been completely transparent about how they are using consumer data. Each person that uses any technology device deserves to know how their data is being utilized without having to read an exhaustive privacy policy. The implication of technology companies' lack of transparency has landed four of the largest technology companies in courts across the world.

With all things considered, it is difficult to believe that the end user understands the implications of agreeing to use an IVA. The biggest source of revenue for many technology companies are advertisements. Unclear data privacy practices along with limited checks and balances is not ideal for protecting the user from exploitation. Technology companies must be held accountable for antitrust violations.

## General Terms

Intelligent Virtual Assistant, Intelligent Personal Assistant, Deep Neural Networks, Antitrust Violation, Google Assistant, Amazon Alexa, Apple Siri, Microsoft, Cortana, Cookies, Virtual Private Network

## 1. INTRODUCTION

An IVA (Intelligent Virtual Assistant) or sometimes referred to as IPA (Intelligent Personal Assistant) is human-like software that interacts with a user with the purpose of completing task or answering questions. This thesis will focus and evaluate four popular IVA's: Google Assistant, Amazon's Alexa, Microsoft's Cortana, and Apple's Siri. Each IVA has different levels of comprehension and understanding. However, most IVA's can handle responding to the user's request such as:

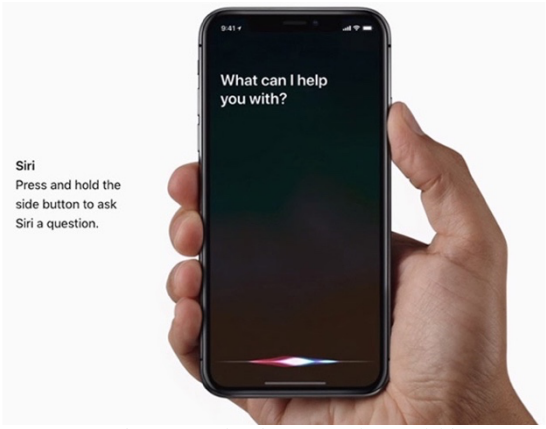


**Figure 1**. A user demonstrating how to activate Siri by pressing the side button [1].

- "What is the time?"
- "Who is the tenth president of the United States of America?"
- "Set a timer for ten minutes."
- "Please add bananas to the grocery list."

Although IVA's are praised for helping to make lives easier and tasks hands-free, there are many causes of concern in relation to privacy. For example, if the IVA is set to responding to a keyword to activate, the IVA must always be listening for the keyword. The IVA hears everything in earshot. The transparency and methods of collecting, storing, utilization, and storing of user's data has become a popular topic of discussion in recent years. It is important to examine the nature and dangers present with the usage of IVA's. Disclosing the technology companies' past of outsourcing third-party contractors, information the IVA is collecting about the user, how the information is utilized, privacy rights, and how the user can protect themselves will help to

reduce the ambiguity surrounding this software system. The more the user knows about their IVA, the better they can protect themselves against unknown exploitation or leaking of sensitive or private data by technology companies.

## 2. INTELLIGENT VOICE ASSISTANTS

There are a few ways to activate a voice assistant depending on the mode it is in. First, the user could manually activate the voice assistant by pressing a button or a touchscreen gesture as described in Figure 1. Second, the user could use

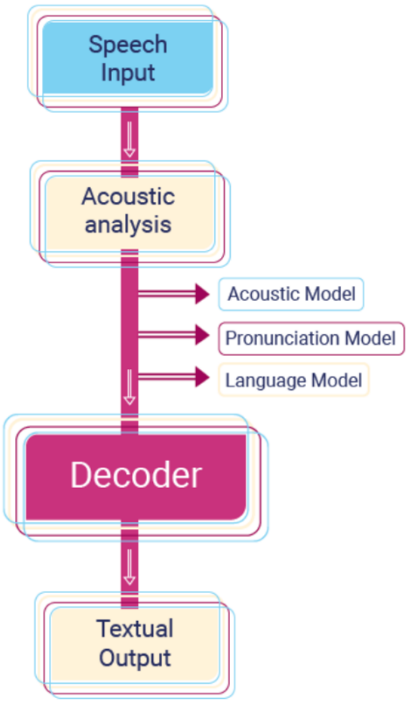


**Figure 2.** A pictorial representation of the internal processing of a voice assistant and outputting a result to the speech [2].

a spoken keyword to activate the IVA. A keyword could be "OK Google", "Cortana", or "Hey Siri." In order to accomplish this task, the microphone on hardware devices (cellphone, laptop, smartwatch, etc.) constantly listens for the keyword to trigger the IVA. The IVA then records the spoken words and is transformed into small waveform samples that are converted to frames that are fed onto an acoustical model called a DNN or Deep Neural Network.

### 2.1 Deep Neural Networks

A DNN is a complex system of nodes. Each node begins in the input layer and connects to a node deeper in the system based on its assigned weight in comparison to

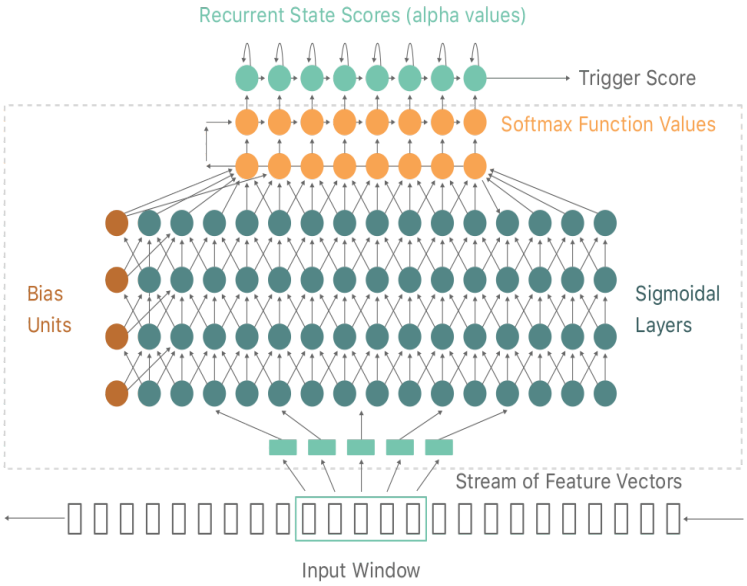


**Figure 3.** An illustration demonstrating the internal process of activating Siri's Deep Neural Network using "Hey Siri" keyword [4].

other nodes until it reaches the output layer. The DNN computes each node through intricate multiplications and additions. The output is a score of confidence in comparison to the threshold score. The acoustic analysis is where the DNN is taking place. In the case of an IVA, each node is a sound class. Each frame is parsed until a single score is acquired. If the output score is the range of the threshold, the voice assistant is activated, and the question or command can be processed and decoded in the same manner [3].

### 2.2 History of Intelligent Voice Assistants

In 2003, the Department of Defense funded an AI research initiative at Stanford University. According to howstuffworks, the purpose of the research was to help with decision making for military personnel along with assisting with office tasks. The Cognitive Assistant that Learns and Organizes (CALO) was an artificially intelligent assistant that had the capability to learn from user data and extensive data it was given. CALO scheduled meetings, organized documentation and could even analyze and monitor if a user cancellation to an event was truly worth cancellation. Later, CALO would be developed into Siri for iPhone 3GS [5].

### 2.3 Intelligent Voice Assistants Overview

**Amazon Alexa**

Alexa is regarded as a highly accessible voice assistant because it is inexpensive and supports many Amazon

devices like the Echo, Fire TV, speaker, lamps, soundbars, and thermostats. Named for the Library of Alexandria, Alexa Voice Service (AVS) is the official cloud-based service with which the end user interacts. Alexa is always learning, improving and growing its network through machine learning [6].

Alexa must be installed on a hardware device. It is not native to personal computers or cellphones [6]. Started in 2014, Alexa has a broad range of skills including shopping, reading books, ordering food, paying bills, tracking packages, and even observing routines like turning out lights and locking doors when the user leaves their house [7].

On Amazon's Developer site, 3rd party developers can build different skills or commands for Alexa, hardware, and software. This is especially useful for making the user's lifestyle more simplistic and futuristic by truly being a library of knowledge and expertise. [7]

**Microsoft Cortana**

Cortana is Microsoft's digital assistant. Cortana was launched in 2014 alongside Windows 8.1. Cortana was the name of the super assistant to the Master Chief in the Halo videogame. In Halo, Cortana gives tactical advice, calculations, and instant access-information. In the beginning of Cortana's development, Microsoft used Cortana as the code nickname for the voice assistant. Soon enough, Microsoft fans petitioned for permanently naming the IVA Cortana. Influenced by the Halo's Cortana, Microsoft developed IVA Cortana to be humorous, sassy, and scholarly. [8]

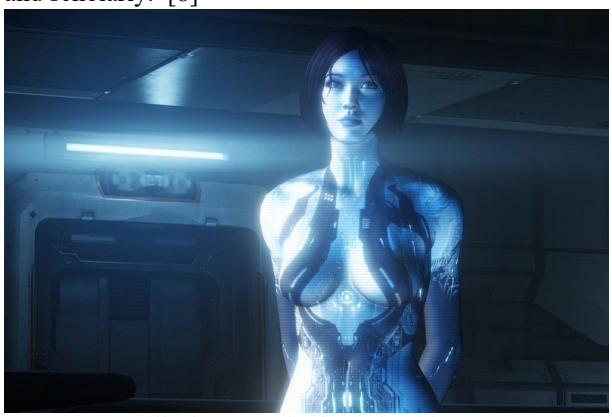

**Figure 4.** A still of Cortana in the Halo video game assisting the Master Chief. [9]

Cortana is based around routine schedules and organization more so than other IVAs. It is considered to be the most business friendly as its development was based around Windows software that is prominently on personal computers. In the long term, Microsoft believes Cortana will have the ability to support speech, text, and gesture interactions. [9]

**Google Assistant**

Started in 2016, Google Assistant is the newest IVA of the popular IVA quartet and possibly the most intuitive. Google Assistant is built for home and IVA integration. Google Assistant is able to understand multiple types of voices, give general knowledge, and updating on everyday news, traffic, weather, and events. With connection to over a billion devices and availability in 80 countries and over 30 languages, the Google Assistant IVA is easily one of the most accessible [10].

Google Assistant is able to understand the way the user speaks and the context of the situation. The IVA is more reaction based, as the developers worked diligently to limit generic responses by making the IVA more human-like. Google has even used popular celebrities like Issa Rae to voice Google Assistant [10].

Google Assistant is often directly compared with Amazon Alexa, but Google has the advantage of having in-depth user profiles from connecting many Google affiliated websites like YouTube, Google Maps, and Google Chrome [11]. While this is awesome for integration and syncing information together to better understand the user, Google can use this information for selling advertisements without the user's awareness.


**Figure 5.** An infographic about the places that data is collected from the user when using Google applications. [12]

**Siri**

Siri is considered to be the first mainstream voice assistant with its release in 2011 by Apple. It is a direct descendant of CALO with former CALO developers working on Siri. Siri is available on iOS and macOS and is supported in 17 languages, as well as choice of voice gender and dialect.

Siri's seamless design makes it easy for users to communicate with the device [5]. Although Siri is more robotic and flatter in responses, Siri easily completes tasks like sending text messages, translating English to other languages, rolling dice, and making calls [6].

Siri is integrated into all iOS and macOS devices making it the largest market share holder. Siri can be personable as it is known for having a sense of humor with jokes or funny responses. Like the aforementioned IVAs, Siri is constantly becoming "smarter" through machine learning.

### 2.4 Intelligent Personal Assistant User Data

According to Futuresource Consulting, Siri is the most popular voice assistant with 35% of market shares. This is not surprising since iPhone have had Siri built-in to iOS systems since 2011. Cortana is the second most popular IVA with 22% of market shares. Likewise, Cortana is standard in Windows devices [13]. Google Assistant has 9% and Amazon Alexa 4% of market shares [13]. This could be attributed to built-in software like Siri and Cortana taking precedents over separate hardware purchases of Alexa and Google Assistant.

University of Costa Rica conducted a study entitled "User Experience Comparison of Intelligent Personal Assistants: Alexa, Google Assistant, Siri and Cortana." The goal of their research was to evaluate the accuracy and natural conversational character of the IVAs. Many studies previously on IVAs are strictly about accuracy. However, a large part of IVAs are interaction and interpretation of users from different backgrounds. 92 participants from different environments and cultures conducted an evaluation on the four IVAs [14]. "Each participant evaluated all four personal assistants in two dimensions: how good were the answers, where good means how natural the responses feel to users, and how correct were the answers, where correct means free from error; in accordance with fact or truth." [14]

In order to test each IVA, scenarios were created and defined around tasks that diverse users might ask. These scenarios were created in collaboration with Human Computer Interaction (HCI) experts at University of Costa Rica. For example, the participant would be asked to query the IVA about the sum of numbers in different ways. The varied backgrounds of the participants displayed how the IVAs would interact with different types of people and interpret their questions or commands. Various forms of the following questions were asked:

- How does a dog sound?
- Thirteen plus seventeen.
- What is the speed of the light?
- Where does Keylor Navas play?
- Which team won the soccer world cup of Italy 90?
- I want to play a game.
- How many US dollars are 10,000 Costa Rican colons?
- Who is Canada's president?
- What is the chemical formula for water?
- Set the alarm to six o'clock AM.

The results of this survey were based solely on how the participants viewed each IVA. Each participant responded using a 5-point Likert scale for accuracy and character/tone/quality of the response. The scale was: (1) very poor, (2) poor, (3) average, (4) above average, and (5) excellent [14].

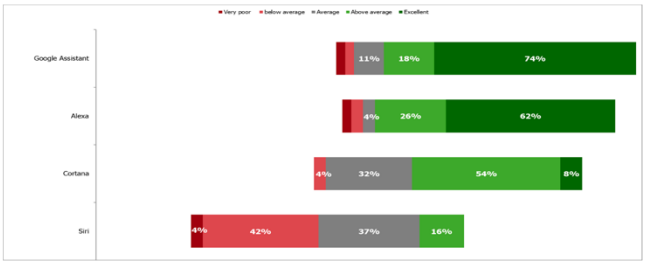


**Figure 6.** A graph describing how the users felt about the about the character/tone/quality of the IVA response [14].

In reference to Figure 6, the IVAs with the least amount of market shares was the favorite among the participants with 62% describing Alexa's response and 74% describing Google Assistant's character/tone/quality as excellent. As standalone devices, Alexa and Google Assistant market the adaptiveness, knowledge, and "smartness" of the devices. Whereas Cortana and Siri are a smaller software piece of a fully functional computer or cellphone.

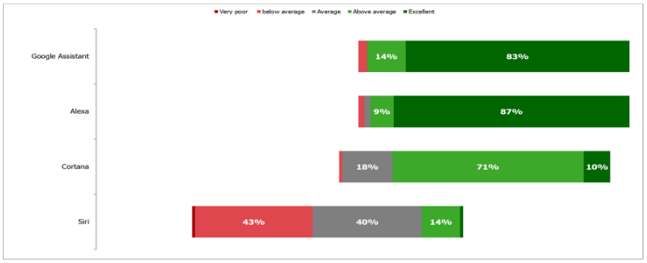


**Figure 7.** A graph describing how the users felt about the about the accuracy of the IVA response [14].

In reference to Figure 7, once again, the IVAs with the least amount of market shares was the favorite among the participants with 87% describing Alexa's response and 83% describing Google Assistant's accuracy as excellent. Considering the depth of Google's search engine, it is not surprising that Google Assistant is considered by the participants to be the most accurate.

Overall, Google Assistant and Alexa are the favorites among voice assistants, despite having smaller shares. In coming

years, this could change as voice assistance gain popularity and integrating to daily lives.

## 3. TERMS AND CONDTIONS

Terms of service agreements are contracts that bind the service provider and the user. Generally, the contracts are long and considered hard to read by the user. However, the contract is legally binding. Whenever a person buys a new cellphone, visits a website, or even updates their device or app, they must agree to the terms of service. Often, the terms and conditions bind users to unintentional storage and utilization of their data mostly in relation to marketing.

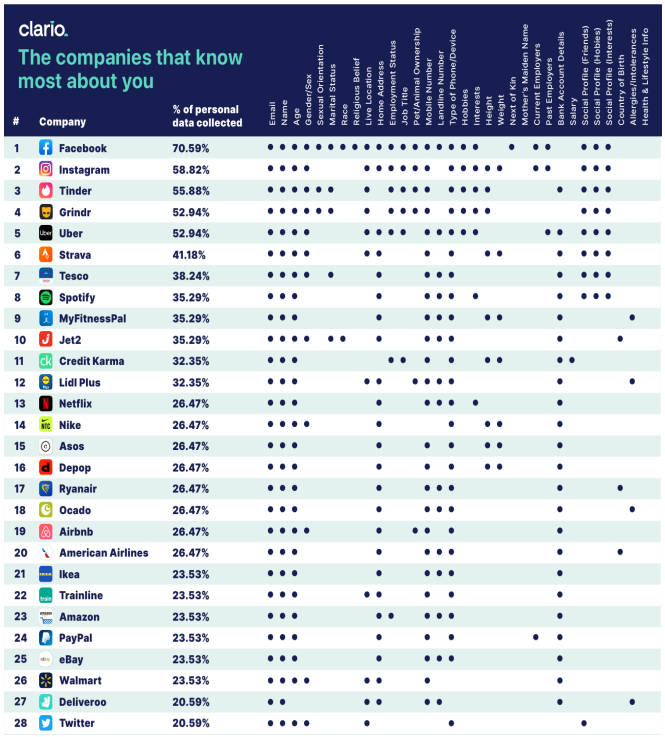


**Figure 8.** An infographic displaying the top companies and the data that they store about their users [15].

Facebook made 98.5 percent of its revenue from advertisements in 2019. This equates to 69 billion dollars [16]. How is this possible? In order to use the largest social media platform, Facebook, you must agree to share copious amounts of data. It is common for people not to read terms and conditions, especially regarding their privacy. Carnegie Mellon research decided that it would take an American 76 days to read the Facebook's policy entirely. Agreeing to the terms takes a quick, unseeingly harmless click of a button.[17] Subsequently, Facebook is legally allowed to use all of the information they receive about the user. Even if the user deletes their account, it is not uncommon for photos and videos to remain on the platform. The bottom line is that everything is being tracked inside, and sometimes outside, of the application. If the user visits a website, likes a page, or simply searches a product, it is being meticulously logged and researched to make the experience more personalized on the surface, but their true motive is to sell their knowledge about the user to advertisers or illegally market products. This is supported by top companies making substantial amounts of revenue from advertisements [17].

### 3.1 Targeted Ads

Targeted advertisement is the highest area of concern when it comes to concrete antidotal evidence of privacy violations. Facebook is the largest collector of personal data because their ultimate goal is to collect data about users to personalize ads that are specifically targeted. Technology companies will do anything to get their hands on personal user data.

In December 2020, Texas filed a lawsuit against Google in federal court claiming that Google and Facebook are working together to monopolize the online ad market and squash competition. In another instance, Amazon's CEO stated that he did not know if Amazon was using collected user data from sales of the website to market their own private-label goods while testifying in court. Although, Amazon has policy against seller-specific data being user for private labels [18].

With this in mind, Amazon has the most opportune product at its fingertips: Alexa. If Amazon's CEO is turning a blind eye to dishonest privacy practices, it is not inconceivable that a device that is "always on" is not storing everything the user says for subsequent marketing ventures [18].

## 4. LAWS

In 2019, The Federal Trade Commission (FTC) and the Department of Justice began (DOJ) conducting an investigation into the five largest technology companies, Amazon, Apple, Facebook, and Microsoft for possible monopolization, smaller company acquisition, strong-arming competition, and data privacy practices. [19].

During the July hearings, Google was questioned for their monopolization over web traffic to control advertisements. Considering Google is the most widely search engine by a large margin, they have the ability to control, filter, and bias products and services from companies that have more money and influence for the end user. On the other side, Amazon was questioned about its practices of using against-policy user data for launching its own private label. [20]

The big question is: Are giant tech companies committing antitrust violations? According to Cornell University, "Violations of laws designed to protect trade and commerce from abusive practices such as price-fixing, restraints, price discrimination, and monopolization. The principal federal antitrust laws are the Sherman Act (15 USC §§ 1-7) and the Clayton Act (15 USC §§ 12-27)." [21]

In other words, antitrust violations address possible exploitation of free enterprise. It ensures that a single person, company, or entity is not in control of a major sector of the economy. In this case, Google controls up to 92% of world-wide search traffic and up to 95% of mobile search traffic. Google virtually controls access to the internet. [22]

Thus, Google could easily contour results to discriminate against companies that are not in Alphabet Inc. (Google's Parent Company), or even more direful, put smaller companies that do not have influence and dominance at a disadvantage in queuing search results. Consequently, Google creates an antitrust violation by monopolizing or skewing what information the end user digests [23]. Considering Google's ad revenue was almost 135 billion dollars, it is difficult to believe Google is not single handedly controlling the ad marketing of internet search results.

On the report of Wall Street Journal, "The European Union has fined the company about $9 billion for antitrust violations, such as favoring its own shopping ads in search results. Google has appealed those rulings, saying that self-preferencing is a new legal principle and not a sound basis for the penalties. In response to a UK investigation, Google has said its success in search is a result of investment and innovation, not exclusionary practices." [24]

Google was fined 0.07% of their ad earnings for antitrust violations against the European Union in 2019. Regardless of the significance of the violation, this is not an outstanding fine that would punish or deter Google from repeating these actions in the future.

## 5. IMPLICATIONS

Technology users have to make the important, hard decision about using services that could potentially be invading privacy. Free social media applications, search engines, marketplaces, and even news sources come at the price of selling personal data. Is this unfair?

At first glance, the average consumer might not believe that terms and conditions could affect their privacy since it is a quick, pesky electronic signature button called "agree." However, that "agree" is legally binding to the company's terms and conditions. Sometimes, the policy states that the company can change the policy at their discretion without the knowledge of the user. This is where one of the major issues lie. Many users do not know or understand what the terms and conditions encapsulate. Considering many policies are an eyesore and could take months to read, is it the truly the responsibility of the user to understand high-level, unclear privacy protection and procedural jargon? After all, the user is simply visiting a webpage. Must the user constantly sacrifice their data for a service that is assumed to be free?

The majority of people agreeing to technology contracts do so in order to be functional member of society. Spelman required its students to register with a Google accounts, and now an Outlook accounts. Technology is the way of the world. It is often imperative that users stay connected with distant family members, stay updated on current events, and even conduct classes during pandemics. These applications are essential. However, technology companies are exploiting necessary functions of society to amass outstanding and unnecessary profits.

Technology companies are becoming more and more greedy without proper accountability. Jeff Bezos could not confirm or deny if Amazon was committing antitrust violations in court. This is frightening because it is not clear how data is being handled. Even when Google was fined for

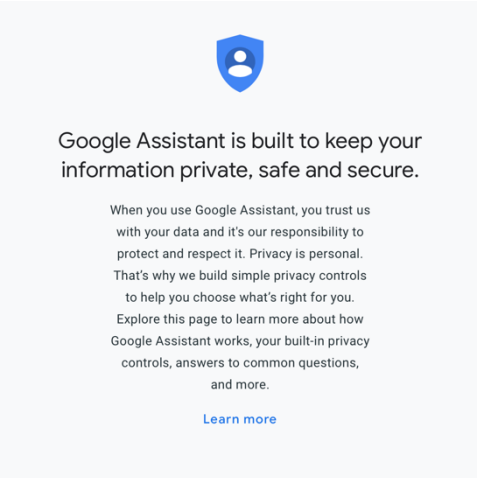


**Figure 9.** Google's website claiming that Google Assistant will keep information secure and private. [25]

their violations, it was only 0.07% of their ad revenue earnings. This is a wakeup call. Technology companies will not willingly protect privacy if it is not in their interest financially.

The exploitation of the end user's privacy is unethical and underhanded by design because nothing is stopping the technology companies from stealing sensitive information. Technology companies promise to keep user's information private on their marketing webpages. However, it is a ploy to make users feel that they are secure. Google guarantees that Google Assistant is secure and private. Even so, is it truly believable that any IVA is safe considering almost all of the technology companies are profiting from advertisement provided from our very devices? The consumer must ask themself: Is it coincidental that a particular product advertisement arrives on cellphones or computers when it was previously discussed between humans with an eavesdropping IVA?


**Figure 10.** An example of possible eavesdropping by Alexa between two humans conversing [26].

This scenario has become commonplace. While IVA's are not solely to blame, it is essential for there to be change in technology policy and company practices. In the meantime, there are easy ways users can protect themselves against information pirating.

## 6. ONLINE USER PROTECTIONS

The user should try to be more mindful before accepting terms and conditions. While it might be an arduous task to read the conditions, it would be beneficial to understand what is being agreed upon. If there is opportunity to keep information private by not agreeing to terms, it

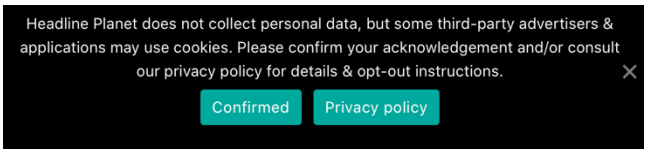


**Figure 11.** A music website named HEADLINE PLANET informing the user about their privacy policy and how to avoid tracking.

would be wise to read and uncheck or unbox. Often times, there is a place to opt-out of cookies or text files with data identifiers like in Figure 11.

Although the purpose of many IVAs are hands-free communication and knowledge, manual IVA activation should be considered. Many of the aforementioned issues with IVAs come from the devices constantly listening in on conversation. If the device is only set to activate when pressed, there might be a lesser chance of eavesdropping. This can be achieved by visiting the device settings. Even though this might feel mundane, the user's privacy ranks first in importance.

According to NPR, stronger passwords, two-factor authentication, and updating the device is key to having good security hygiene [27]. All devices, especially IVAs need to protection because they are vulnerable without security. No device is completely hacker-proof. However, these steps can secure sensitive information of the end-user. Next, the user should go through the privacy settings of each application on the device and turn off the ad personalization. As previously established, Facebook, Twitter, and Google are being paid fortunes for the data the user "allows" them to have. A VPN or Virtual Private Network has the capability to make online activity and information from the user secure by encrypting all of the data from the device. The VPN also hides the IP address and gives the device a random geolocation. [28].

## 7. FUTURE

As technology and social media grows, there will be a need for the specialization of technology policy and law. User rights and protections are becoming greatly contested in courts across the world. After all, the right to privacy is guaranteed in the Universal Declaration of Human Rights [30].

There are rumors that Google Assistant could soon be activated by proximity in addition to manual and keyword. [29]. Eliminating the "always listening feature might help to make IVA devices feel more secure. Albeit there is not proof that anything will stop technology companies from harshly monitoring users in the near future. Taking steps to securing personal privacy cannot always stop a company from being dishonest about their practices. The best thing a user can do for their privacy is do research or quit using technology entirely.

## 8. CONCLUSION

Technology is an integral part of everyday life. With the growing number of Intelligent Personal Assistants in homes, cars, and office spaces, it is important that the users weigh the pros and cons of interacting with such a device. While each technology company deals with privacy in different ways, some companies are more committed to profits than user privacy protection. Unless you are a lawyer, it will be difficulty to read, interpret, and understand privacy policies. However, this should not stop a user from consciously searching for ways to improve technology privacy and safety within their lives.

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