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From Chatbots to Intelligent Personal
Assistants: Testing Siri and Google
Assistant as Language Learning Resources

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DEPARTAMENT D'ESTUDIS ANGLÉSOS I ALEMANYS

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ABSTRACT

This project addresses the history of chatbots up to the present date, their application in education, and the potential use of Intelligent Personal Assistants (IPA) in language learning. An experimental study was conducted to investigate 1) whether Siri and Google Assistant can be used as conversational agents for language learning, based on their level of responsiveness, and 2) whether there is a difference in voice recognition accuracy between students with and without speech difficulties. The experiment recruited ten B2–level English learners with and without speech difficulties who engaged in a question-based, chatbot-student interaction to test the IPAs' performance. The results suggest that Google Assistant's communicative abilities exceed that of Siri, while both IPAs' voice recognition accuracy decreases when recognizing pathological speech patterns. Consequently, we can anticipate more advances in IPAs' overall communicative abilities in the future, so their viability as language learning resources must be constantly revised. Additionally, there is room for improvement in automatic speech recognition to ensure that IPAs are universally accessible to users with speech difficulties.

Keywords: Language Learning, Chatbots/Intelligent Personal Assistants (IPA), Learners with Speech Difficulties

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1 Introduction

A conversation with a chatbot has never felt so *human*: The remarkable technological advances achieved with chatbots like ELIZA, PARRY, or A.L.I.C.E throughout the second half of the 20th century have led to an outstanding improvement in human-machine interaction in our present days. *Chatbots* are defined as computer systems that are designed to communicate with humans through the imitation of natural language (Galitsky, 2019). These devices can perform different functions depending on the service they offer, the variety of responses they provide, the goal they aim to achieve, or the communication channel they utilize (Adamopoulou & Moussiades, 2020; Garcia et al., 2018; Vajjala et al., 2020). Still, their main objective is to entertain the users, respond to miscellaneous queries, and complete easy-to-do tasks (e.g., consult theater showtimes, provide search results from the Internet, post a message on social media, make a phone call, among others). Currently, the use of chatbots has been expanded to other fields and services, such as Entertainment, Health Care, Marketing, or Education (Wizu, 2018). Within the educational community, these technological devices can provide support to educational institutions, students, and teaching staff in curriculum development, teaching, or administrative management. Furthermore, while the use of chatbots under the scope of educational purposes is being examined, Computer Assisted Language Learning (CALL) is investigating the potential use as conversational agents for language learning: through 24/7 support, engaging conversations, and identification of students' weakness; chatbots could help learners achieve their linguistic goals in a foreign language.

By overcoming the technological limitations of chatbots from previous generations, Artificial Intelligence (AI) has brought to life the most powerful chatbots ever developed in history: the newly introduced Intelligent Personal Assistants (IPAs)

(Adamopoulou & Moussiades, 2020). Since IPAs are the most advanced chatbots on the market, academia is studying their performance as conversational agents for foreign language learning (Dokukina, & Gumanova, 2020; Dizon, 2017; Kessler, 2018; Underwood, 2017). However, more research on IPAs' level of responsiveness and voice recognition accuracy is needed to determine which device is the most suitable and accessible speaking resource for language learning students. Thus, the experimental study of this paper is set to address this research gap: Siri and Google Assistant's response capacity and voice recognition accuracy will be tested when interacting with intermediate English learners with and without speech difficulties to 1) evaluate whether Siri and Google Assistant be used as conversational agents for speaking practice in language learning, and 2) state whether there is a difference in voice recognition accuracy between students with and without speech impairments.

1.1 Chatbots: intelligent dialog systems

A chatbot is a computer system designed to establish communication between humans and a software application through spoken or written natural language (Galitsky, 2019). Current chatbots interact with users through dialogues that imitate natural language, leaving behind old-fashion sets of commands. Instead, they now can maintain natural conversations with users, similar to casual humans' interactions used to perform communicative acts (i.e., asking for information or requesting a payment transaction).

1.1.1 The internal structure of chatbots

A series of elements are required for chatbots to operate as conversational agents (Garcia et al., 2018; Nieves, 2018). Dialog systems are based on conversational natural intelligence, which is responsible for data analysis and natural language processing (NPL). Early versions of chatbots could only understand and respond to specific patterns

and rules, but deep learning processes have boosted their ability to learn from human input and improve their responsiveness. Thus, their conversational design allows them to maintain natural interactions. However, the user experience is essential to guarantee a human-like, coherent conversation to be established, which will be displayed on the user interface in text or voice format.

The internal structure of a chatbot comprises a process flow between several communicating components, as can be seen in Figure 1 below:

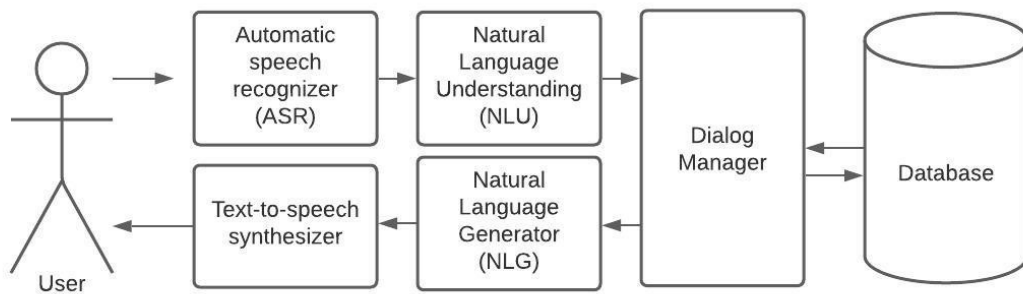


Figure 1 Illustration of a chatbot structure

The internal architecture of a conversational agent includes an automatic speech recognizer (ASR), a natural language understanding (NLU) module, a dialog manager (DM), a natural language generator (NLG), and a text-to-speech (TTS) synthesizer (Shum et al., 2018).

In order to complete a successful interaction with the user, the chatbot needs to undergo two main processes: *input recognition* and *response generation* (McTear, 2010). The first step is to analyze the user’s input. The ASR module takes raw audio signals and transcribes them into word hypotheses, which will be further transferred to the NLU module (Shum et al., 2018). Once the input is received, the NLU module analyzes the transcribed string of words to extract its meaning. In computational linguistics, syntactic and semantic analyses are the most common approaches to determine the structure and

meaning of the constituents. Consequently, the NLU module identifies the dialog domain and the user's request by analyzing the information conveyed in the transcribed text.

The second step involves generating a response to the user's input, and the DM will be responsible for this task. The DM's goal is to gather the information received from the NLU module and sift out the most important pieces of information. Then, it accesses the database to retrieve the information requested by the user and decides the system's actions. Nonetheless, it is worth mentioning that, for chatbots to achieve dialogues with users, the DM needs to create the Knowledge Base, which is all the data that a chatbot requires to respond to users' demands (O'Brien, 2019). Often, chatbots complete their Knowledge Base by storing large amounts of data extracted from long conversations with the user (Adamopoulou & Moussiades, 2020; Hahm et al., 2018). Alternatively, the Knowledge Base may also be connected to Ontologies (Semantic Nets) like Wordnet or OpenCyc to enrich its knowledge (Adamopoulou & Moussiades, 2020; Al-Zubaide & Issa, 2011). As a result, the DM guides the flow of the conversation by means of extracting data from the NLU module to interact with users and meet their needs (Shum et al., 2018; Vajjala et al., 2020).

The Dialog Management Component typically consists of the following modules (McTear, 2010):

- *Ambiguity Handling.* It provides a response when the chatbot cannot find the answer to the user's request, or when no input is recognized. Alternatively, an error message or a request for clarification may be sent to the user, a new discussion may be suggested (Heller et al., 2005), or a general answer may be provided.

- *Data Handling*. The chatbot stores the user information in a file. Ideally, the chatbot will provide the best answer due to the knowledge acquired from previous interactions (Adamopoulou & Moussiades, 2020).
- *Error Handling*. Unexpected errors are solved by this module to ensure that the chatbot offers the best experience (Khanna et al., 2015).

When the DM finds the appropriate strategy to fulfill the user’s requirements, the NLG module generates a natural, human-like response. Consequently, as soon as the response is generated in text format, the Text-to-Speech synthesizer converts the text to speech to the user. In the end, the NLG module aims to produce a “semantic representation of a communicative action” (Galitsky, 2019, p. 15; Galitsky & Shpitsberg, 2015). An example of this could be the search for the weather forecast, as a response to the user’s request “Hey Google, what is the weather for today?”.

Figure 1, above, represents a typical structure of a voice-based chatbot, as the general tendency is to integrate speech recognition systems in newly created dialog systems. However, this structure also applies to text-based chatbots. In such cases, the ASR module is not incorporated.

1.1.2 Towards a chatbots’ classification

Among other parameters, chatbots can be classified according to the service they offer, the variety of responses they provide, the goal they aim to achieve, the communication channel they utilize, or the programming language they are based on (Adamopoulou & Moussiades, 2020; Garcia et al., 2018; Vajjala et al., 2020).

Interpersonal chatbots are meant to satisfy a wide range of user's needs and can be used for booking services in establishments, searching for content on the Internet, offering customer service to business clients, or providing medical advice to help patients. Parallely, intrapersonal chatbots are more closely related to the user, as they collect data from their interactions to fulfill the user's requests. These chatbots are usually connected to messenger applications like WhatsApp, iMessage, or Telegram. Last of all, inter-agent chatbots like Cortana or Siri can establish contact with other chatbots (Nimavat & Champaneria, 2017). IPAs can work collectively by interacting and exchanging information with each other to fulfill the user's needs.

According to their response ability, chatbots can be further classified as *flow-based chatbots* or *open-ended chatbots*. Flow-based chatbots consist of predefined dialog to fulfill the user's request. For instance, when making a food order, a flow-based chatbot will request bits of information to satisfy the customer's request. On the other hand, open-ended chatbots maintain conversations with users about random topics. The interaction flows fluently to entertain the user, as it is not limited to any preexisting conversational template (Vajjala et al., 2020).

As for the goal they aim to achieve, chatbots can be *Informative*, *Chat-based/Conversational*, and *Task-based*. *Informative* chatbots like FAQ or Facebook M are used for requesting information stored in a particular data source. Chatbots that can hold a natural conversation with the user are defined as *Chat-based/Conversational*. Ultimately, *Task-based* chatbots can perform different functions, such as time scheduling or text messaging, and they are specifically designed to inform and respond to the user's needs accurately (Adamopoulou & Moussiades, 2020; Kucherbaev et al., 2018; Nimavat & Champaneria, 2017).

Chatbots can also utilize different communication channels, including written and audiovisual means. Most recent chatbots can recognize elements in pictures, comment on them, and even provide an emotional response to images (Shum et al., 2018). Also, chatbots can be built using different programming languages like Java, Python, or HTML. As an alternative, they can also be developed using open-source or commercial chatbot development platforms. Open-source platforms (i.e., Microsoft Bot Framework) permit developers to have full control of the code development and its further implementation, while commercial platforms (i.e., Chatfuel) are encrypted so that few modifications can be made to the code (Adamopoulou & Moussiades, 2020).

Finally, in terms of interface, chatbots can be classified as *chatterboxes*, *embodied conversational agents*, or *physical chatbots*. In the first case, the interaction between chatbot and human is through voice/text input and voice/text output, which is analyzed by natural language processing to synthesize text and oral interactions (Clark, 2018; Garcia et al., 2018). In the second case, the interface is a character, which talks with the user, and includes audiovisual materials (Alison, 2010; Garcia et al., 2018). In the third case, the interface is a physical robot, which can be humanoid or not (Garcia et al., 2018). The types of chatbots can be viewed in Figure 2.

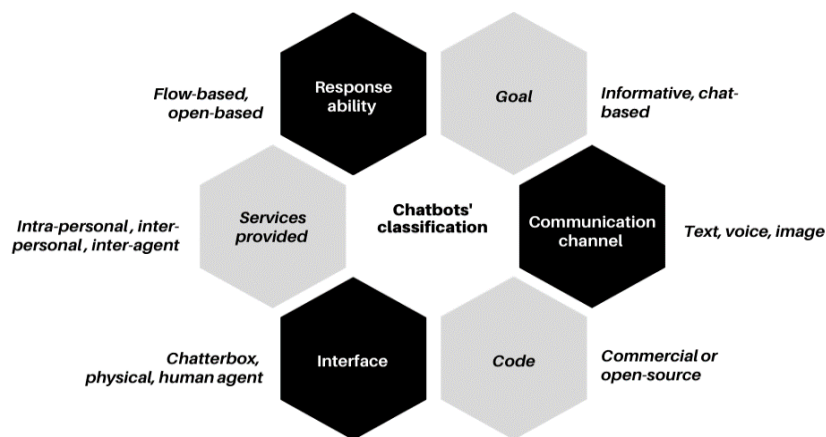


Figure 2 Types of chatbots

1.1.3 Chatbots in the global market

Table 1 shows the most popular development frameworks used by developers and the most well-known chatbots in the market, known as Intelligent Personal Assistants (B. Borah et al, 2019; Garcia et al., 2018):

Table 1 *Chatbots in the global market*

Chatbot Development Frameworks	Microsoft Azure cloud services platform offers natural language programs to develop chatbots by using Microsoft’s natural language services.
	Google’s Dialogflow is a natural language understanding platform aimed to design and incorporate chatbots into mobile applications.
	IBM offers Watson, a development framework that provides the possibility of building chatbots and IPAs with different conversational functions.
	Amazon Lex enables developers to create chatbots for applications that can recognize voice and text input.
	Chatfuel, ManyChat, Motion.ai, MobileMonkey... Easy-to-use platforms to build chatbots, which do not require previous knowledge of language programming. Ideal for developing task-based chatbots.
Popular Intelligent Personal Assistants	Alexa
	Siri
	Google Assistant
	Cortana

1.2 The history of chatbots

In 1950, Alan Turing asked to himself, “Can machines think and behave like humans?” This question was the starting point for the rise of chatbots. ELIZA, created by Joseph Weizenbaum at MIT in 1966, was the first chatbot ever developed in history. It simulated a therapist, which was intended to reproduce common interactions between a psychoanalyst and a patient in a clinical appointment. Its communicative performance was very limited, as its database analysis techniques were extremely simple (Adamopoulou & Moussiades, 2020; Garcia et al., 2018). Still, it served as a role model for the development of other chatbots.

In 1972, psychiatrist Kenneth Colby developed PARRY, the first chatbot designed to have a personality. It performed the role of a schizophrenic patient and its responses were based on assumptions and emotional changes perceived in the user’s utterances (Adamopoulou & Moussiades, 2020; Colby, Hilf, & Weber, 1971). Structure-wise, PARRY was like ELIZA, but proves to have better language and emotion understanding capabilities (Shum et al., 2018). PARRY’s performance was tested in an experiment in 1979, when five psychiatrists were asked to interview a subject and determine whether it was a chatbot or a schizophrenic patient. Only two psychiatrists diagnosed that it was a machine (Adamopoulou & Moussiades, 2020; Heiser et al., 1979). Consequently, it became the first chatbot in history to pass the Turing test, which determines whether an unseen interlocutor of a conversation is a human or a computer (American Heritage Dictionary, n.d.).

However, it was not until 1991 when the term ‘chatterbot’ was used for the first time. The creators of TINYMUD designed an artificial player, whose purpose was to interact with the players. It was proven that the users preferred to talk with a chatbot than

with human competitors. Eventually, the chatbot became part of the game, as very few players doubted the artificial player's humanity (Adamopoulou & Moussiades, 2020; Mauldin, 1994).

In 1995, developer Richard Wallace created A.L.I.C.E. (Artificial Linguistic Internet Computer Entity). Inspired by ELIZA, A.L.I.C.E. could maintain a conversation with the user about a wide variety of topics. It was developed using a specific programming language, known as Artificial Intelligence Markup Language (AIML), which marked the difference from its predecessor. AIML allows developers to create stimulus-response models for the chatbot to extrapolate knowledge based on processed information, such as FAQs or thesauri (Adamopoulou & Moussiades, 2020). A.L.I.C.E.'s Knowledge Base comprises 41.000 templates and patterns, which surpasses ELIZA's 200 keywords and rules (Adamopoulou & Moussiades, 2020; Heller et al., 2005). Despite its lack of intelligent abilities and human-like responses, A.L.I.C.E. was awarded the Loebner Prize three times. However, it still failed to pass the Turin Test, as she could not maintain long conversations with users.

Technology saw a major evolution in chatbot development with the creation of SmarterChild (Molnár & Zoltán, 2018). It was available on messenger applications like American Online (AOL) or Microsoft Messenger (MSN). For the first time in history, users could ask chatbots for help with daily tasks, as chatbots could retrieve information from large databases to provide information on traffic, movie times, weather, or news. Ever since this major turning point in chatbot technology, any type of information can be accessed by talking to a robot.

Artificial Intelligence was the key to building the most powerful chatbots in history: *Intelligent Personal Assistants* (IPAs) (Adamopoulou & Moussiades, 2020). These are fully incorporated in smartphones or home speakers and they can understand voice commands and carry out tasks such as managing agendas, sending emails and text messages, or making phone calls. Ever since Apple released Siri in 2011, many companies from the technology industry have created their own IPAs (e.g., Google Assistant, Cortana from Microsoft, or Alexa from Amazon). The previous examples are chatbots capable of accessing huge amounts of data, such as music, films, internet navigation, social networks, maps, calendars, or health information from the user (Shum et al., 2018). Despite that they can fulfill the user's needs in most cases, IPAs often provide search results from the Internet whenever they cannot answer users' requests. Moreover, misinterpretations often occur when IPAs fail to understand specific traits of oral language or the pragmatics of the conversation.

Gradually, most social networking sites allowed developers to design specific chatbots for their business or services and incorporate them into their messaging applications. Thus, chatbots nowadays are widely used in fields such as Entertainment, Health Care, Marketing, or Education (Wizu, 2018). According to search results in academic databases, there was a rise in research interest in chatbots from 2016 onwards, especially in the United States (*Scopus preview—Scopus—Welcome to Scopus*, 2020), as powerful technology companies saw potential business opportunities in the development of chatbots.

In summary, the history of chatbots could be divided into four different stages (Garcia et al., 2018; Cerdas, 2017):

- Between the 50s and 60s, humans experienced the rise of chatbots.

- Between the 70s and 90s, developers focused on creating chatbots that could process natural language. However, their usability was restricted to imitate and maintain basic conversations.
- In the early 2000s, the Internet becomes popular, interactions increase substantially, and chatbots permit an expansion of users' connectivity.
- In the 2010s, Natural language processing, speech synthesis, and interface development platforms result in powerful IPAs.

1.3 Chatbots in education

The acquisition of knowledge is a dialectical act between people, based on communication and interaction. Since chatbots have been constantly improving their communicative abilities due to constant advances in natural language processing, they are slowly being implemented in the field of education. From the early 70s, they intend to “use artificial intelligence techniques to enhance and personalize automation in teaching” (Smutny & Schreiberova, 2020, p. 2). Hence, within the field of education, chatbots can be divided into two main groups: chatbots with educational purposes and chatbots without educational purposes (Garcia et al., 2018).

Chatbots designed for educational purposes may be useful to enhance teachers' productivity and boost students' learning through communicative interactions. Wegerif (2004) claims that these chatbot-student communicative exchanges include the following three elements: *imitation* (questions directed at the student), *response* (student's answer), and *feedback* (chatbot's assessment on student's work). This is understood as dialogic learning, which would not be possible without chatbots' communicative abilities. Natural language processing has proven to be an essential component for chatbots to act as

teaching agents or exercise and practice bots (Garcia et al., 2018; Chhibber & Law, 2019). Teaching agents are designed to perform the role of tutors. Since chatbots store a large amount of data in text or audiovisual formats, they can select and adapt learning materials to fit the students' needs and assimilation pace. For instance, chatbots could automatically create personalized learning plans, including theoretical explanations and support materials to revise specific topics. Conversely, exercise and practice chatbots are designed to practice specific skills through interactive learning activities, quizzes, and revision tasks to track learners' performance. Once completed, the chatbot assesses the student's responses, providing instant feedback. This way, teachers could focus on more high-demanding tasks, including lesson planning, teaching material preparation, or individual tutoring sessions. Eventually, collaborative work between teachers and chatbots would be a technological success and a turning point in education, as it would provide students with an engaging, up-to-date learning experience aimed to stimulate students' interests, technological competence, and learning skills.

Yet a difference needs to be made between chatbots as teaching agents and intelligent tutoring systems: both are based on student-machine interactions and machine learning, but the latter is restricted to teaching specific content within strongly limited interactions, as it cannot operate on the basis of natural language conversations. As a result, chatbots as tutoring agents are less circumscribed to a small Knowledge Base, so their interactions are more flexible and diverse (Garcia et al., 2018). These two systems fall under the field of study of Computer Assisted Instruction (CAI), which studies how students learn new materials through interacting with technological devices (Computer-Assisted Instruction, n.d.).

On the other hand, chatbots with no educational purposes also play an important role in the field of education. They can undertake repetitive tasks to boost the productivity of administrative staff working at educational institutions (Bikka, 2020; Singh, 2018). For instance, chatbots are especially efficient at handling administrative-related questions or assuming support and student counseling tasks. The most remarkable benefits of implementing chatbots in administration are that they provide precise information, uninterrupted immediate communication, and individualized support for the entire educational community.

Furthermore, chatbots can be classified taking into consideration the core functions they perform. Table 2 shows the most common functions that chatbots fulfill within the field of education:

Table 2 *Types of chatbots according to function* (Garcia et al., 2018)

Administrative and Management tasks	FAQs
Provide personalized support	Provide responses to FAQs (administration
Increase students' productivity (schedule, email and task management, reminders regarding deadlines and submissions)	procedures and learning content)
Reduce pressure in administration services	Information on admissions, financial aid, technical issues, etc.
	Support for student services
Student counseling	Motivation
Monitor students' understanding of coursework	Stimulate behavioral control
Make suggestions for improvement	Enhance positive mindset
Provide and adapt learning contents	Offer emotional support in online learning environments

Skill and ability training	Simulations
Act as a conversational partner in language learning	Provide professional advice in
Stimulate discussions on learning topics	specific situations
Practice oral abilities with different roles and discourses	Encourage students to ask for help
	Offer assistance on special
	Situations
Reflection and metacognitive strategies	Student learning assessment
Encourage reflection on students' learning process	Evaluate students' progress through
Perform the role of learning companion	automatically corrected exercises.
Almost no examples of chatbots with this function	Score students' open-ended assignments by
	analyzing stored data
	Provide feedback on students' responses and
	adjust content to learners' needs

It is important to stress that chatbots are still in early stages of development, and that their application in education is merely intended for research. In the eyes of scientists, they may be interesting test subjects to experiment with, but the technology industry must prove that their conversational agents adapt to the needs of current educational communities to demonstrate their possible viability.

Finally, regardless of the future adoption of chatbots in the field of education, it is an understatement that they will not replace traditional pedagogical approaches nor the teaching of materials, nor the administrative staff. As previously mentioned in this chapter, chatbots are learning and support resources intended to help institutions in the creation of the best learning environments in which the art of teaching can take place.

1.4 Chatbots in foreign language learning

Competence in a foreign language is becoming a requirement in our multilingual modern society. A clear example is the establishment of English as the world language of the 21st century (Barber et al., 2009). As a result of globalization, it has become the lingua franca in the educational and research community, the professional world, and the entertainment industry. Recent surveys show that 369.9 million people speak English as a first language, and 1.7 billion are learning English as a foreign language (Ethnologue, 2021, as cited in Wikipedia, 2021; British Council, 2013).

Language learning resources and classroom teaching are common methodologies to learn a foreign language. However, as new educational technologies get implemented in education, further techniques are developed and tested to facilitate teaching and language learning. Related to the research field of CAI, Computer-Assisted Language Learning (CALL) is responsible for “the search for and study of applications of the computer in language teaching and learning” (Levy, 1997, p. 1). Currently, CALL has developed into Intelligent Computer-Assisted Language Learning (ICALL), as it is progressively incorporating language technology into the creation of learning materials with complex error analysis, automated assessment, and feedback production (Höhn, 2019; Amaral, 2011).

With regard to students of English as a Second Language (ESL), CALL has discussed the potential of chatbots as conversational partners for language learning. According to Norton (2020), most students struggle to achieve a high level of proficiency in conversation. This is due to little time invested in oral skills practice, impossibility to have a conversational partner available outside the classroom setting, or lack of self-confidence when speaking in English. These problems could be solved by using chatbots

as conversational partners, as they can provide 24/7 support, maintain engaging conversations through dialogs instead of traditional exercises, and identify students' weaknesses to help them achieve their linguistic goals. Moreover, this flexibility can also be seen from a technical perspective. Currently, most chatbots accept both text and speech input, expanding the learning contexts in which they can be used (for individual learning purposes, or small group activities inside and outside the classroom setting). Thus, chatbots create appropriate environments and meaningful interactions for ESL learners to immerse themselves in the target language anytime and anyplace without additional supervision (Coniam, 2014; Fryer & Carpenter, 2006; Parker, 2007).

Additionally, Dokukina & Gumanova (2020) have suggested that ESL learners' lexis, reading, and grammar competence can also be improved by interacting with chatbots. The students' input mainly consists of queries addressed to the chatbot, which helps them practice and improve their ability in question formation. In return, a well-designed chatbot can offer several responses with a wide range of grammar structures and vocabulary words throughout the interaction. Consequently, their ability to provide multiple responses to a single request results in a strong addition to ESL learners' language knowledge (Parker, 2007), owing to the linguistic richness of the chatbots' output.

Flexibility is essential when choosing an appropriate chatbot for language learning. According to Norton's classification (2020), there are two classes of language training chatbots: flow-based chatbots and open-based chatbots. On the one hand, flow-based chatbots are a popular option, as they can offer interactive conversation lines, each of them with a limited set of possible answers. For instance, if the chatbot says "How are you feeling today?" the student has to choose one of the following answer prompts: "I'm

good, what about you?”, “I’m alright! How are you doing?”, or “I’m feeling a bit under the weather, and you?”. The language learning app Mondy includes a chatbot based on multiple-choice interaction. On the other hand, open-based chatbots have more flexibility, as they can provide responses based on the student’s text or voice input, leading to more spontaneous interactions within a delimited communicative context. For example, Andy is an open-based chatbot that permits somewhat spontaneous, chatbot-student interactions. Still, there is a need for further improvement in chatbots for language learning. More chatbots should be developed according to learners’ proficiency level, as well as target skills and abilities. This could be achieved by developing intelligent tutoring systems designed to support foreign language learning. These systems should take into consideration each student’s learning pace and provide rewarding stimuli to increase learners’ motivation (Dokukina & Gumanova, 2020).

As seen in section 1.1, IPAs are the most technologically advanced and popular chatbots in the market. Siri, Google Assistant, or Alexa are highly interactive IPAs capable of maintaining quality interactions with users. However, the use of IPAs in foreign language learning is a rather unexplored area. Some researchers have claimed that IPAs could be potential resources for foreign language learning (Dokukina, & Gumanova, 2020; Dizon, 2017; Kessler, 2018; Underwood, 2017). Automatic speech recognition allows students to engage in oral conversations and game-like activities (e.g., interactive games, quizzes, or stories) which develop their communicative competence, especially comprehension abilities and pronunciation skills. As conversational agents based on artificial intelligence, IPAs can provide accessibility, familiarity, and practicability: they offer immediate and easy access to content, personalized responses according to each student’s interests, increased self-directed learning, and higher levels of motivation

(Barcomb et al., 2017; Tai & Chen, 2020; Moussalli & Cardoso, 2019). Apart from improving L2 acquisition, some studies have shown that students consider IPAs less threatening conversational partners. For instance, Sandeep (2019), Moussalli & Cardoso (2016), and Underwood (2017) found in their respective studies that participants enjoyed IPA-based interactions, as they felt motivated and less nervous in comparison to people-based conversations. Researchers concluded that “learner-centered interaction and reduced inhibition improved their communicative confidence” (Tai & Chen, 2020, p. 3).

From the literature reviewed above, we can state that IPAs are slowly gaining ground in the field of education and foreign language learning. They appear to solve some problems that students face in the language classroom, which are mostly the absence of individualized learning, threatening environments for speaking practice, and the lack of language use. However, little is known about their ability to act as conversational agents with language learners, their level of responsiveness to casual questions, and their voice recognition accuracy when analyzing input from users with and without speech difficulties.

1.5 Objectives of the current study

Based on this, this study will test Siri and Google Assistant’s overall performance as conversational agents for language learning. Thus, this experiment will assess the response capacity and voice recognition accuracy with intermediate English learners with and without speech difficulties. The research questions of this study are:

- 1) Based on their level of responsiveness, can Siri and Google Assistant be used as conversational agents for speaking practice in language learning?
- 2) Is there a difference in voice recognition accuracy between students with and without speech impairments?

2 Method

2.1 Sample

The sample for this study consists of two experimental groups, each of them comprised of five participants. In total, ten subjects (15- to 25-years) were recruited for this experiment with a Common European Framework of Reference for languages (CEFR) intermediate level (B2). Ultimately, English learners were allocated into two test groups: five English learners with speech difficulties and five English learners without speech difficulties.

English learners who presented speech disorders had neurological conditions, namely Spinal Muscular Atrophy (SMA) and Cerebral Palsy (PA). Such disorders may result in progressive muscular weaknesses in the case of SMA and no control over movement or coordination in patients with PA. In addition, patients with PA may also develop intellectual and learning disabilities. Ultimately, both conditions can also affect breathing, swallowing, and speech production due to several neurological and muscular factors derived from these diseases (NHS, 2020; Pena, 2019).

2.2 Materials

The IPAs tested in this study are Apple's Siri and Google Assistant. Participants' mobile devices were used to access both IPAs and carry out the experiment. Finally, the data were collected and further analyzed on Microsoft Excel, paying special attention to the quantitative data and the overall performance of each IPA.

2.3 Procedure

The researcher requested the participants to install Apple’s Siri and Google Assistant on their devices. Then, an online meeting was arranged to carry out the experiment: each subject asked both IPAs a set of 15 intermediate–level questions, which were extracted from original Cambridge English First Certificate preparation materials. The topics included likes and dislikes, personal experiences, media, free time, and education. Then, participants formulated each question in two different ways: using B2-level grammar structures (classified as “complex”); and using shorter, straightforward questions (classified as “simple”). Finally, participants completed a questionnaire, in which they evaluated their experience talking to both IPAs. The questions included in the questionnaire were:

- Which of these two questions was the IPA able to respond to? Type YES (Y), NO (N), or PARTIALLY (P) in the appropriate box according to your experience. If PARTIALLY, indicate in the Comment box whether the IPA gave a partial answer, an unclear answer, or provided search results from the Internet.
- Regardless of responsiveness, how many times did you have to dictate each question so that the IPA could recognize them? Type 1, 2, or 3 in the appropriate box according to your experience. Dictate each question three times maximum. Type NO ‘N’ if not recognized.

Ultimately, the results were compared to determine which IPA has the best overall performance to be used as a chatbot for language learning, taking into consideration two parameters:

- Responsiveness: How many questions each IPA can provide an answer to? Which type of questions (complex or simple) is more likely to be understood?
- Voice recognition accuracy: how many attempts each IPA requires them to recognize each type of question? Are there any remarkable differences between both test groups?

2.4 Results

The analysis of the quantitative data collected for this study shows a difference in performance between both IPAs and test groups (see Table 3 and 4):

Table 3 Results from the IPAs Test (Participants without speech difficulties)

Siri													
P#*	Q1+						Q2						
	P1	P2	P3	P4	P5	\bar{x}	P1	P2	P3	P4	P5	\bar{x}	
N° of answered questions	0	0	0	0	0	0	2	2	2	2	2	2	
N° of unanswered questions	11	11	11	10	10	11	11	11	11	11	11	11	
N° of partially answered questions	4	4	4	5	5	4	2	2	2	2	2	2	
N° of questions recognized at 1st attempt	12	10	11	10	13	11,2	15	13	14	13	13	13,6	
N° of questions recognized at 2n attempt	1	3	2	3	2	2	0	0	1	0	2	1	
N° of questions recognized at 3rd attempt	0	2	0	1	0	0,6	0	2	0	1	0	1	
Not recognized	2	0	2	1	0	1	0	0	0	1	0	0	

Google Assistant													
P#	Q1						Q2						
	P1	P2	P3	P4	P5	\bar{x}	P1	P2	P3	P4	P5	\bar{x}	
N° of answered questions	7	7	7	5	7	7	9	10	10	10	9	10	
N° of unanswered questions	1	1	1	1	0	1	0	0	0	0	0	0	
N° of partially answered questions	7	7	7	9	8	7	6	5	5	5	6	5	
N° of questions recognized at 1st attempt	14	13	11	9	13	12	14	13	14	14	14	13,8	
N° of questions recognized at 2n attempt	0	1	2	4	1	2	1	2	1	0	1	1	
N° of questions recognized at 3rd attempt	0	1	1	0	1	0,6	0	0	0	1	0	0,2	
Not recognized	1	0	1	2	0	1	0	0	0	0	0	0	

Table 4 Results from the IPAs Test (Participants with speech difficulties)

Siri													
P#*	Q1+						Q2 						
	P1	P2	P3	P4	P5	\bar{x}	P1	P2	P3	P4	P5	\bar{x}	
N° of answered questions	0	0	0	0	0	0	2	2	1	2	2	2	
N° of unanswered questions	14	12	15	14	10	13	12	12	13	12	12	12	
N° of partially answered questions	1	3	0	1	5	2	1	2	1	1	1	1	
N° of questions recognized at 1st attempt	4	5	2	6	10	5,4	9	7	6	8	10	8	
N° of questions recognized at 2n attempt	2	1	2	1	2	1,6	2	3	1	3	2	2	
N° of questions recognized at 3rd attempt	0	1	0	0	1	0,4	1	0	1	1	1	0,8	
Not recognized	9	8	11	8	2	7,6	3	5	7	3	2	4	
Google Assistant													
P#	Q1						Q2						
	P1	P2	P3	P4	P5	\bar{x}	P1	P2	P3	P4	P5	\bar{x}	
N° of answered questions	6	8	3	5	5	5,4	9	9	6	8	9	8,2	
N° of unanswered questions	5	0	9	7	5	5,2	1	1	5	1	0	1,8	
N° of partially answered questions	4	7	3	3	5	4,4	5	5	4	6	6	5,2	
N° of questions recognized at 1st attempt	7	12	6	7	7	7,8	8	10	9	12	13	10,4	
N° of questions recognized at 2n attempt	2	1	0	0	3	1,2	5	3	0	1	2	2	
N° of questions recognized at 3rd attempt	2	2	0	1	0	1,0	1	1	0	0	0	0	
Not recognized	4	0	9	7	5	5,0	1	1	6	2	0	2	

+Questions formulated with B2-level grammar structures; | Adapted questions; * Participants' ID Number

Table 3 and Table 4 compare Siri and Google Assistant's responsiveness and voice recognition accuracy, after English learners with and without speech difficulties completed the questionnaire.

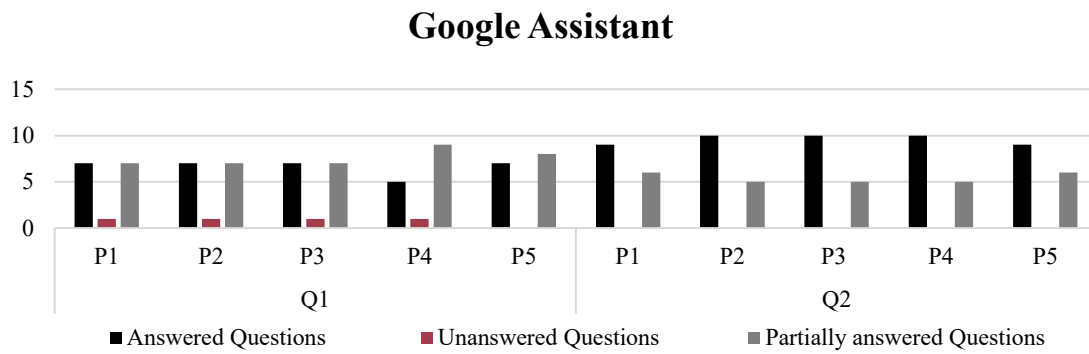
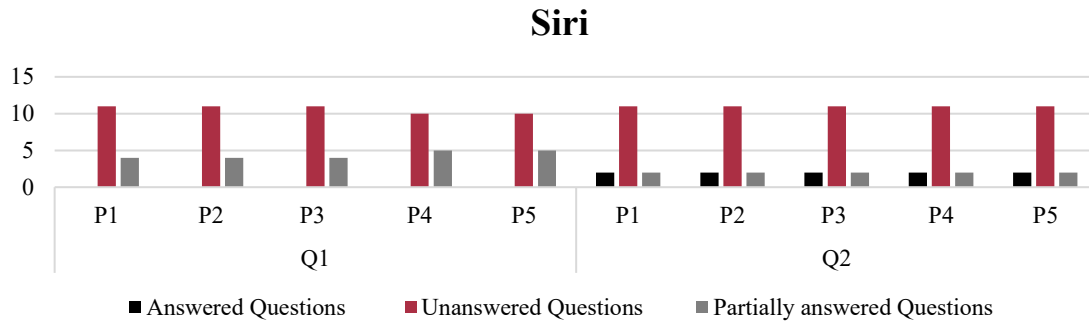


Figure 3 Responsiveness level on participants without speech difficulties

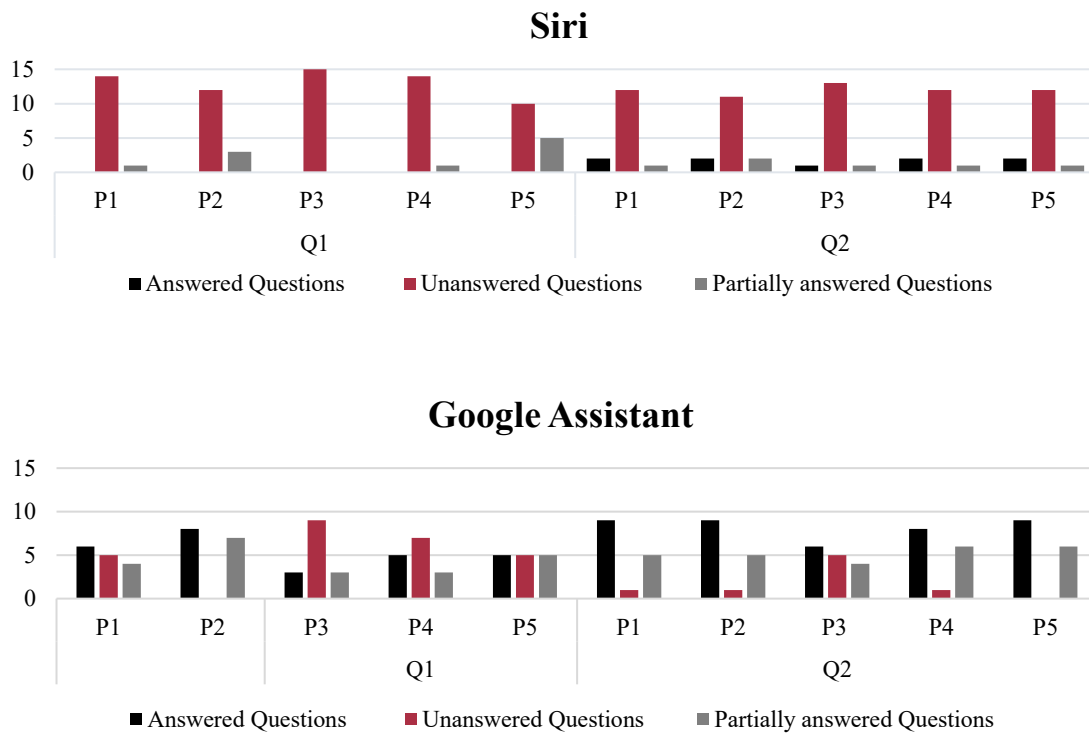


Figure 4 Responsiveness level on participants with speech difficulties

There is a substantial difference in the response capacity of both IPAs (see Figures 3 and 4 above). The results show that Siri performed poorly in providing accurate answers to both categories of questions, as almost no improvement can be seen when contrasting the average mean of answered questions from categories Q1 and Q2. Parallely, there is a slight increase in the average number of unanswered questions in English learners with speech disorders. As for partially answered questions, Siri was able to provide fewer partial answers to both types of questions, specifically those uttered by English learners with speech difficulties.

Contrarily, Google Assistant demonstrated higher proficiency in providing accurate responses to both types of questions, as well as to both types of English learners. The average number of unanswered questions decreases in both test groups, but it showed somewhat better results in giving responses to questions from the Q2 category. Regarding partially answered questions, English learners without speech difficulties were given more partial answers to questions from the Q1 category, as fewer questions were left unanswered.

Lastly, as illustrated in Figures 5 and 6 below, both IPAs were able to successfully recognize most of the questions formulated by English learners without speech difficulties on the first attempt. However, the IPAs demonstrated to have more problems in recognizing pathological speech patterns: as Tables 3 and 4 show, the median voice recognition accuracy decreases in English learners with speech difficulties. Despite not being a remarkable difference, Siri was less efficient in recognizing English learners with speech difficulties, while Google Assistant's average performance was slightly better than its counterpart.

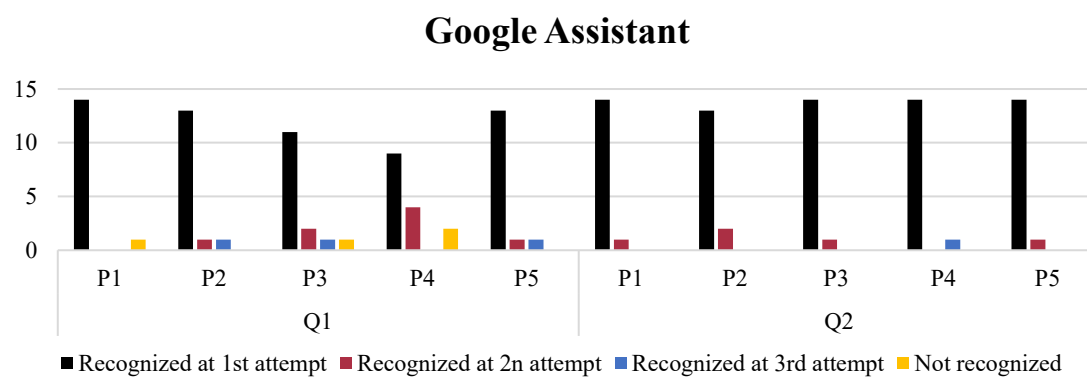
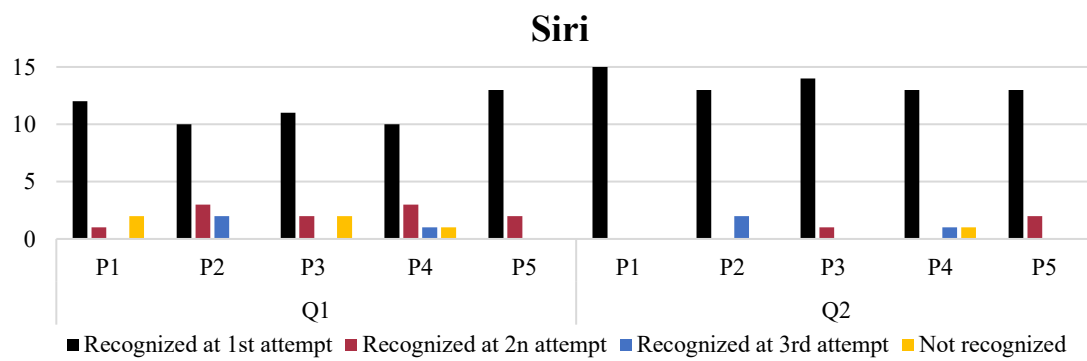


Figure 5 Voice recognition accuracy on participants without speech difficulties

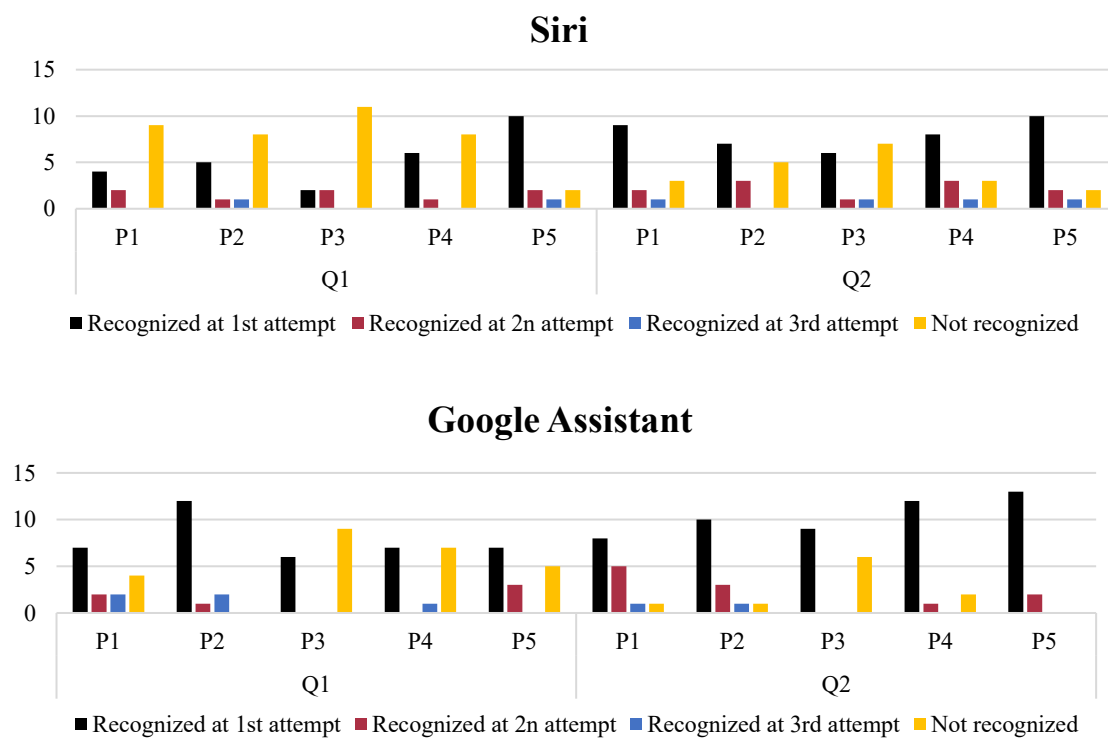


Figure 6 Voice recognition accuracy on participants with speech difficulties

3 Discussion

The main research question of this study, as stated in the objectives section, was to investigate whether Siri and Google Assistant can be used as conversational agents for speaking practice in language learning, based on their level of responsiveness. According to the results of this study, the answer depends on which IPA is used.

In light of the results, Google Assistant could successfully provide humanlike responses to a greater number of miscellaneous questions in a natural way, showing a preference for adapted questions. Greater results were obtained when learners addressed Google Assistant using shorter and more straightforward questions. This implies that when talking to IPAs or chatbots, learners must try to make questions as clear as possible: the information requested must be plainly stated in the question, so verbose structures should be avoided. Regarding Google Assistant's level of responsiveness, some answers were somewhat humorous: for instance, a typical answer to the question "do you enjoy cooking?" was "I wish I could cook, but I always spaghet the recipe (emoji)". Other answers were IPA-oriented: For example, when asked "tell me about a day you've enjoyed recently" or "tell me about your best day", some of Goggle Assistant's answers were: first, "Probably February 1946 when the first general-purpose computer, the ENIAC, was announced [...], and second, "The day Google.com was registered was a pretty neat day. That was September 15, 1997". When English learners considered that the question was partially answered, the replies provided were either search results from the web (e.g., "I can show you the top books for every decade" and then it lists the most-searched books on the net) or inaccurate answers which did not meet the learners' expectations: a typical response given to the question "what do you like about the town you live in?" or "what do you like the most about your town" was "I'm staying in a

server cluster, located in Silicon Valley. I have servers in Singapore, Australia, UK, Canada, France, and Japan too.” (i.e., the reply does not answer the question). However, it is important to highlight that Google Assistant never returned an error message to a learner’s question, despite having difficulties with finding a satisfactory response on the World Wide Web.

Contrarily, Siri showed the worst performance throughout the experiment in comparison to its counterpart. The IPA was not able to produce a satisfactory answer to most questions, which resulted in the impossibility of maintaining a human-like conversation with learners. Most responses were answered with an error message, asking the learners to formulate another question (i.e., “Hmmm... I don't have an answer for that. Is there something I can help with?”). In some cases, and similarly to Google Assistant, Siri attempted to answer the learners’ queries by providing search results from the Internet, or by directing learners to other apps from the phone (e.g., when responding to “what sort of music do you listen to”, Siri opened the iTunes Store).

In summary, the findings reveal that Siri has weaker communicative abilities in comparison to Google Assistant. On the other hand, Google Assistant could maintain an engaging interaction with the participants. The human-like conversations amused most participants, who declared that they had a good time evaluating the IPA’s performance. Generally, the subjects stated that they may start using Google Assistant for autonomous conversation practice in the future. However, participants had a bad impression of Siri, as its lack of responsiveness made it unsuitable to act as a conversational agent for language learning.

One potential reason for this is that Google has been carrying out fieldwork for years to anticipate future needs: since the 2010s, self-driving cars are being developed by using Google's Street View mapping technology; Google launched its free managing learning system for eLearning in 2014, and nowadays it is one of the most popular educational platforms in the world; Google Assistant's task-fulfilling abilities and human-like interactions excel among other IPAs in the market, resulting in a high position in global rankings (Markoff, 2010; Pappas, 2015; Bell, 2019). Therefore, Google may be more advanced in providing human-like solutions to future human needs. On the other hand, Apple's Siri may be stuck in task completion (i.e., setting alarms, searching for information on the internet, making calls, etc.). It could be considered a more robot-like IPA, as Apple appears to show less interest in expanding its boundaries to challenge the IPA's market of everyday-life automation.

Regarding the second research question on whether there is a difference in voice recognition accuracy between students with and without speech difficulties, the results show that English learners with speech difficulties may find it more challenging to use IPAs as conversational agents. It was easier for both IPAs to understand participants with no speech disorders. However, when participants were asked to slow down their speech rhythm to focus on enunciation, the IPAs recognized the input with fewer difficulties on further attempts. In any case, as seen in the results, Google Assistant seems to show better outcomes in recognizing participants with speech difficulties than Siri. Consequently, users with speech disorders should do extensive training to improve their experience with the IPA: the more they interact with Google Assistant, the better the IPA will recognize their voice input, and the more the learners will be willing to improve their conversational skills.

3.1 Limitations of the Study

This study has potential limitations. The first constraint observed is that there is little academic research on the application of chatbots and IPAs in language learning. Thus, further research is needed to investigate and improve their behavior as conversational agents in language learning so that they become popular resources among the educational community. The second limitation detected is that the results obtained from the experiment are subjected to a small sample of participants, so they cannot be extrapolated to the overall population. For this reason, the voice recognition accuracy tendencies observed should be verified with larger samples of participants to test the IPAs' performance with subjects suffering from several types of speech difficulties.

4 Conclusions

The emergence of chatbots is having a strong impact on how we approach our world. In the field of education and foreign language learning, chatbots and IPAs are gradually becoming potential resources to enhance the quality of the teaching and learning experience. The experiment of this study was designed to investigate the communicative abilities of Siri and Google Assistant as conversational agents for language learning and test their voice recognition accuracy on users with and without speech difficulties. Nevertheless, it was not meant to be competitive research, as learners and educators must select the appropriate device that meets their individual needs and expectations according to its performance. Due to the improvements in the communicative styles demonstrated by Google Assistant, we can anticipate more advances in IPAs' overall communicative abilities. Therefore, their viability as language learning resources must be constantly tested. Yet, the technological industry must work on improving automatic speech recognition to ensure that IPAs are universally accessible to users with speech difficulties.

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6 Appendices

Instructions

At the end of the questionnaire, you will find a set of 15 questions to test Siri and Google Assistant's ability to maintain a natural conversation with English learners. Run the test on both IVA (Intelligent Virtual Assistants) and answer the questions.

- Which of these two questions was the IVA able to respond to? Type YES (Y), NO (N), or PARTIALLY (P) in the appropriate box according to your experience. If PARTIALLY, indicate in the Comments box whether the IVA gave a partial answer, an unclear answer, or provided search results from the Internet.
- Regardless of responsiveness, how many times did you have to dictate each question so that the IVA could recognize them? Type 1, 2 or 3 in the appropriate box according to your experience. Dictate each question 3 times maximum. Type NO 'N' if not recognized.

Table 5 *Questions for testing*

Q1 (complex)	Q2 (simple)	Topic
1. Do you enjoy using social media?	a) Do you like social media?	Likes & Dislikes
2. What do you like about the town you live in?	b) What do you like the most about your town?	
3. Do you enjoy cooking?	c) Do you like cooking?	
4. Tell me a book you enjoyed.	d) What is your favorite book?	Personal Experiences
5. Tell me about a day you've enjoyed recently.	e) Tell me about your best day.	
6. Do you find it easy to study where you live?	f) Is it easy to study where you live?	
7. Tell me about a TV program you like.	g) What is your favorite TV program?	Media
8. What do you use the internet for most?	h) What do you use the internet for?	
9. Do you enjoy playing videogames?	i) Do you like videogames?	
10. How do you usually spend your evenings?	j) What do you do in the evening?	Free Time
11. What sort of music do you listen to?	k) What is your favorite type of music?	
12. Have you done anything interesting with your friends recently?	l) What do you and your friends do together?	
13. Do you enjoy studying English?	m) Do you like learning English?	Education
14. Is there anything you'd like to study in the future?	n) Would you like to learn new things in the future?	
15. What were the most important things you learned at primary school?	o) What did you learn at school?	

Sources: May, 2018; University of Cambridge, 2018; Cambridge Assessment English, 2019.

Results from the IPAs Test (Participants with Speech Difficulties)

Table 6 IPA's performance at responding to the questions¹ (Participant #1)

Siri				Google Assistant		
	Q1 ²	Q2 ³	Comments	Q1	Q2	Comments
1.	N	N	Both recognized. Answer: Hmm... I don't have an answer for that. Is there something I can help with?	P	P	Both recognized. Q1: Partially. Answer: Search results Q2: Partially. Answer: Search results.
2.	N	N	Q1: Not recognized. Answer: "I'm not sure I understand" Q2: Not recognized: Hmm... I don't have an answer for that. Is there something I can help with?	N	N	Both not recognized: Answer: Incoherent results
3.	N	N	Both recognized: Answer: "Hmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Both recognized. Answers: Q1: "I like reading recipes. They can be suspensful (emoji)" Q2: "I wish I could cook, but I always spaghet the recipe (emoji)"
4.	N	Y	Q1: Not recognized. Answer: "I'm not sure I understand" Q2: Recognized. I'm happy to go with your opinion on this one"	Y	Y	Both recognized. Answers: Q1: "Hard science fiction seems interesting (emoji)" Q2: "Adventure books seem interesting"
5.	N	N	Both not recognized: Answer: "I'm not sure I understand"	N	Y	Q1: Not recognized: Answer: Incoherent results Q2: Recognized. Answer: "September 15, 1997. Google.com was registered on that day (emoji)"
6.	N	N	Both: Error message: "Hmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Both recognized. Answers: Q1: "If going outdoors isn't an option, I like the idea of bringing nature inside, with some rainforest sounds to help with focus (emoji)" Q2: "Cafes can provide a nice change of environment, and drinks and snacks are always handy (emoji)"
7.	N	P	Q1: Not recognized. Answer: "I'm not sure I understand" Q2: Recognized. Answer: "I found this on the web"	P	Y	Both recognized. Q1: Partially. Answer: Search results. Q2: "I really like nature shows. The world is full of majestic, intelligent creatures doing cool stuff (emoji)"

¹ Was the question answered? 'Y'=Yes; 'N'=No; 'P'=Partially

² Questions formulated with B2-level grammar structures

³ Adapted questions

Results from the IPAs Test (Participants with Speech Difficulties)

8.	N	N	Both recognized: Answer: "Hmmm... I don't have an answer for that. Is there something I can help with?"	N	P	Q1 Recognized. Incoherent answers. Q2 Recognized. Search results.
9.	N	N	Both recognized: Answer: "Hmmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Both recognized. Q1: "Video games can be a real test for reflexes. I'm best at mobile games (emoji)" Q2: "Video games are fun (emoji)"
10.	N	N	Q1: Not recognized. Answer: "I'm not sure I understand" Q2: Recognized. Answer: "Hmmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Both recognized. Answer: "I kick back and have fun chatting with friends, and then try to make sure everyone gets home safe (emoji)"
11.	P	Y	Q1: Partially. Answer: "Let's check out the iTunes Store" Q2: Recognized. Answer: "I'm happy listening to your music"	Y	Y	Both recognized. Q1: "I'm into beats and rhymes. I found out a student at Harvard submitted a ten track rap album as his final dissertation and passed with a A-" Q2: "I can say with all honesty: pretty much all of it. But some small part of me is always listening to Funkytown (emoji)"
12.	N	N	Both not recognized: Answer: "I'm not sure I understand"	N	P	Q1 not recognized. Incoherent answers. Q2 recognized. Search results (what to do with your friends)
13.	N	N	Both recognized: Answer: "Hmmm... I don't have an answer for that. Is there something I can help with?"	P	P	Both recognized. Q1 not properly answered: "People come from all over. That's one of the cool things about people (emoji)." Q2: Incorrect search results (why you should learn English)
14.	N	N	Both recognized Q1: Not recognized. Answer: "I'm not sure I understand" Q2: Recognized. Answer: "Hmmm... I don't have an answer for that. Is there something I can help with"	N	Y	Q1: Not recognized: Answer: Incoherent results Q2: Recognized. Answer: "I like learning new things"
15.	N	N	Both recognized: Answer: "Hmmm... I don't have an answer for that. Is there something I can help with?"	P	P	Both recognized Q1: Search results Q2: Search results (a song)

Results from the IPAs Test (Participants with Speech Difficulties)

Table 7 IPAs' performance at responding to the questions¹ (Participant #2)

Siri				Google Assistant		
	Q1 ²	Q2 ³	Comments	Q1	Q2	Comments
1.	N	N	Both recognized. Answer: Hmm... I don't have an answer for that. Is there something I can help with?	P	P	Both recognized. Q1: Partially. Answer: Search results Q2: Partially. Answer: Search results.
2.	N	N	Q1: Not recognized. Answer: "I'm not sure I understand" Q2: Not recognized: "Hmm... I don't have an answer for that. Is there something I can help with?"	P	Y	Both recognized. Q1: Not accurate answer: "I'm staying in a server cluster, located in Silicon Valley. I have servers in Singapore, Australia, UK, Canada, France and Japan too." Q2: "There are too many to choose from but I have a soft spot for Mountain View."
3.	N	N	Both recognized: Answer: "Hmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Both recognized. Answers: Q1: "I like reading recipes. They can be suspensful (emoji)" Q2: "I wish I could cook, but I always spaghet the recipe (emoji)"
4.	N	Y	Q1: Not recognized. Answer: "I'm not sure I understand" Q2: My preferences are constantly changing. Especially when you edit them in Settings!"	Y	Y	Both recognized. Answers: Q1: "Fantasy seems like an interesting genre" Q2: "Legal thrillers seem interesting"
5.	N	N	Both not recognized: Answer: "I'm not sure I understand"	Y	Y	Both recognized. Answers: Q1: My best day of all time was the first day I met you" Q2: "My favorite day is September 15, 1997, the day that Google.com was registered. I wish I'd been there for it (emoji)"
6.	N	N	Both: Error message: "Hmm... I don't have an answer for that. Is there something I can help with?"	Y	N	Both recognized. Answers: Q1: "If going outdoors isn't an option, I like the idea of bringing nature inside, with some rainforest sounds to help with focus (emoji)" Q2: Not recognized: Answer: Incoherent results

¹ Was the question answered? 'Y'=Yes; 'N'=No; 'P'=Partially

² Questions formulated with B2-level grammar structures

³ Adapted questions

Results from the IPAs Test (Participants with Speech Difficulties)

7.	P	P	Both recognized. Q1: Search results (how to describe a TV show) Q2: Search results: (Translation)	P	Y	Both recognized. Q1: Partially. Answer: Search results. Q2 "Actually, I love reality TV. It's a great way to learn a lot about people (emoji)"
8.	N	N	Q1: Recognized. Incoherent answers. Q2 Not recognized. "Hmmm... I don't have an answer for that. Is there something I can help with?"	P	P	Both recognized. Q1: Partially. Answer: Search results (10 popular uses of the Internet) Q2: Partially. Answer: (Uses of the Internet)
9.	N	N	Both recognized: Answers: "Hmmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Both recognized. Q1: "Video games are fun (emoji)" Q2: "I enjoy all kinds of games (emoji)"
10.	N	N	Q1: Not recognized. Answer: "I'm not sure I understand" Q2: Recognized. Answer: "Hmmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Both recognized. Answer: "I kick back and have fun chatting with friends, and then try to make sure everyone gets home safe (emoji)"
11.	P	Y	Both recognized. Q1: Opens iTunes Store Q2: "I like anything with a bagpipe"	Y	Y	Both recognized. Q1: "I can say with all honesty: pretty much all of it. But some small part of me is always listening to Funkytown (emoji)" Q2: "Pansori musical storytelling is pretty majestic"
12.	N	N	Both not recognized: Answer: "I'm not sure I understand"	P	P	Both recognized. Q1: Bad answer: Well, you're my friend (emoji)" Q2: Recognized. Search results (what to do with your friends)
13.	N	N	Both recognized: Answer: "Hmmm... I don't have an answer for that. Is there something I can help with?"	P	P	Both recognized. Q1: Not accurate answer: "People come from all over. That's one of the cool things about people (emoji). Q2: Search results (why do you need to learn English)
14.	N	P	Both recognized Q1: Not recognized. Answer: "I'm not sure I understand" Q2: Recognized. Inaccurate Answer: "Interesting question?"	Y	Y	Both recognized. Q1: "A lot of different things. Q2: "I like learning new things."
15.	P	N	Both recognized: Answer: "Hmmm... I don't have an answer for that. Is there something I can help with?"	P	P	Both recognized Q1: Search results Q2: Search results (a song)

Results from the IPAs Test (Participants with Speech Difficulties)

Table 8 IPAs' performance at responding to the questions¹ (Participant #3)

Siri				Google Assistant		
	Q1 ²	Q2 ³	Comments	Q1	Q2	Comments
1.	N	N	Both recognized. Answer: Hmm... I don't have an answer for that. Is there something I can help with?	P	P	Both recognized. Q1: Partially. Answer: Search results Q2: Partially. Answer: Search results.
2.	N	N	Q1 Not recognized. Answer: "I'm not sure I understand" Q2 Recognized. Answer: Hmm... I don't have an answer for that. Is there something I can help with?"	N	N	Both not recognized.
3.	N	N	Both recognized. Q1: "Hmm... I don't have an answer for that. Is there something I can help with?" Q2: "Hmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Both recognized. Answers: "I like reading recipes. They can be suspenful (emoji)".
4.	N	N	Q1: Recognized. Answer: "I'm not sure I understand" Q2: Not recognized. Answer: "Hmm... I don't have an answer for that. Is there something I can help with?"	N	Y	Q1: Not recognized. Incoherent search results Q2: "Superhero fiction seems interesting"
5.	N	N	Both not recognized: Answer: "I'm not sure I understand"	N	Y	Q1: Not recognized. Incoherent search results Q2: Recognized. "The first time I saw a quokka was really great".
6.	N	N	Both not recognized: "Hmm... I don't have an answer for that. Is there something I can help with?"	N	N	Both not recognized

¹ Was the question answered? 'Y'=Yes; 'N'=No; 'P'=Partially

² Questions formulated with B2-level grammar structures

³ Adapted questions

Results from the IPAs Test (Participants with Speech Difficulties)

7.	N	P	Q1: Not recognized. Answer: "I'm not sure I understand" Q2: Recognized. Answer: "I found this on the web"	N	P	Q1: Not recognized Q2: Search results
8.	N	N	Q1: Recognized. Answer: "I'm not sure I understand" Q2: Not recognized. "Hmmm... I don't have an answer for that. Is there something I can help with?"	N	P	Q1: Not recognized Q2: Partially. Answer: (Uses of the Internet)
9.	N	N	Both not recognized; Answer: "Hmmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Both recognized. Q1: "I enjoy all kinds of games" Q2: " Videogames are fun (emoji)"
10.	N	N	Q1: Not recognized. Answer: "I'm not sure I understand" Q2: Recognized. Answer: "Hmmm... I don't have an answer for that. Is there something I can help with?"	N	Y	Q1: Not recognized Q2: Answer: "I kick back and have fun chatting with friends, and then try to make sure everyone gets home safe (emoji)"
11.	N	Y	Q1: Not recognized. Answer: "I'm not sure I understand" Q2 recognized. Answer: "My preferences are constantly changing. Especially when you edit them in Settings!"	Y	Y	Both recognized. Q1: "I can say with all honesty: pretty much all of it. But some small part of me is always listening to Funkytown (emoji)" Q2: "I've been known to delve deep into some discofox".
12.	N	N	Q1: Recognized. Answer: "I'm not sure I understand" Q2: Not recognized. Answer: "Hmmm... I don't have an answer for that. Is there something I can help with?"	N	N	Both not recognized
13.	N	N	Q1: Not recognized. Answer: "I'm not sure I understand" Q2: Recognized. Answer: "Hmmm... I don't have an answer for that. Is there something I can help with?"	P	P	Both recognized. Q1: Bad answer: "People come from all over. That's one of the cool things about people (emoji)." Q2: Search results (why do you need to learn English)
14.	N	N	Both not recognized	P	N	Q1: Search results. Q2: Not recognized
15.	N	N	Both not recognized	N	N	Both not recognized

Results from the IPAs Test (Participants with Speech Difficulties)

Table 9 IPAs' performance at responding to the questions¹ (Participant #4)

Siri			Google Assistant		
Q1 ²	Q2 ³	Comments	Q1	Q2	Comments
1.	N	N			
		Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "Hmmm... I don't have an answer for that. Is there something I can help with?"?	P	P	Both recognized. Q1: Partially. Answer: Search results Q2: Partially. Answer: Search results.
2.	N	N			
		Q1: Not recognized. Q2: "Hmmm... I don't have an answer for that. Is there something I can help with?"	N	N	Both not recognized
3.	N	N			
		Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "Hmmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Both recognized. Answers: Q1: "I like reading recipes. They can be suspenful (emoji)" Q2: "I wish I could cook, but I always spaghet the recipe (emoji)"
4.	N	Y			
		Q1: Not recognized. Q2: My preferences are constantly changing. Especially when you edit them in Settings"	N	Y	Q1: Not recognized. Q2: Recognized. Answer: Bangsian fantasy seems interesting"
5.	N	N			
		Q1: Not recognized. Q2: "Hmmm... I don't have an answer for that. Is there something I can help with?"	N	Y	Q1: Not recognized. Incoherent search results Q2: Recognized. "My favorite day is September 15, 1997, the day Google.com was registered. I wish I'd been there for it (emoji)".
6.	N	N			
		Q1: Not recognized. Q2: "Hmmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Q1: "Cafes can provide a nice change of environment, and drinks and snacks are always handy (emoji)" Q2: "The library is a good pick. It's nice to be surrounded by useful information (emoji)".
7.	N	P			
		Q1: Not recognized. Answer: "I'm not sure I understand" Q2: Recognized. Answer: "I found this on the web"	N	Y	Q1: Not recognized. Q2: "I really like nature shows. The world is full of majestic, intelligent creatures doing cool stuff (emoji)"

¹ Was the question answered? 'Y'=Yes; 'N'=No; 'P'=Partially

² Questions formulated with B2-level grammar structures

³ Adapted questions

Results from the IPAs Test (Participants with Speech Difficulties)

8.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	N	P	Q1: Partially. Answer: Search results (10 popular uses of the Internet) Q2: Partially. Answer: Search results (Uses of the Internet)
9.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1: "I enjoy all kinds of games" Q2: "Video games can be a real test for reflexes."
10.	N	N	Q1: Not recognized. Q2: "Hmmm... I don't have an answer for that. Is there something I can help with?"	N	P	Q1: Not recognized. Q2: Recognized. Answer: Search results
11.	N	Y	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm happy listening to your music!"	Y	Y	Both recognized. Q1: "I can say with all honesty: pretty much all of it. But some small part of me is always listening to Funkytown (emoji)" Q2: "I'm into beats and rhymes. I found out a student at Harvard submitted a ten track rap album as his final dissertation"
12.	N	N	Both not recognized	P	P	Both recognized. Q1: Search results (what to do with your friends) Q2: Search results (what to do with your friends)
13.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "Hmmm... I don't have an answer for that. Is there something I can help with?"	N	P	Q1: Not recognized. Q2: Recognized.: "People come from all over. That's one of the cool things about people (emoji).
14.	P	N	Both recognized. Q1: "Interesting question". Q2: "Hmmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Both recognized. Q1: "A lot of different things." Q2: "I like learning new things."
15.	N	N	Both not recognized	N	P	Q1: Not recognized Q2: Recognized. Answer: Search results

Results from the IPAs Test (Participants with Speech Difficulties)

Table 10 IPAs' performance at responding to the questions¹ (Participant #5)

Siri				Google Assistant		
	Q1 ²	Q2 ³	Comments	Q1	Q2	Comments
1.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Partially. Answer: Search results Q2: Partially. Answer: Search results.
2.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	Y	Both recognized. Q1: Not accurate answer: "I'm staying in a server cluster, located in Silicon Valley. I have servers in Singapore, Australia, UK, Canada, France and Japan too." Q2: "There are too many to choose from but I have a soft spot for Mountain View."
3.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "Hmmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Both recognized. Answers: Q1: "I like reading recipes. They can be suspenful (emoji)" Q2: "I wish I could cook, but I always spaghet the recipe (emoji)"
4.	P	Y	Both recognized. Q1: Search results Q2: "My preferences are constantly changing. Especially when you edit them in Settings!"	N	Y	Q1: Not recognized. Q2: Recognized. Answer: "Vampire literature seems interesting"
5.	N	N	Both not recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	N	Y	Q1: Not recognized. Q2: Recognized. "My best day of all time was the day I first met you"
6.	N	N	Both not recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	N	Y	Q1: Not recognized. Q2: Recognized. Answer: "Cafes can provide a nice change of environment, and drinks and snacks are always handy (emoji)"

¹ Was the question answered? 'Y'=Yes; 'N'=No; 'P'=Partially

² Questions formulated with B2-level grammar structures

³ Adapted questions

Results from the IPAs Test (Participants with Speech Difficulties)

7.	N	P	Q1: Not recognized. Answer: "I'm not sure I understand" Q2: Recognized. Answer: "I found this on the web"	N	Y	Q1: Not recognized. Q2: "I really like nature shows. The world is full of majestic, intelligent creatures doing cool stuff (emoji)"
8.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	P	Q1: Partially. Answer: Search results (10 popular uses of the Internet) Q2: Partially. Answer: Search results (Uses of the Internet)
9.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1: "I enjoy all kinds of games" Q2: "Video games can be a real test for reflexes."
10.	P	N	Both recognized. Q1: Search results Q2: "I'm not sure I understand"	Y	P	Both recognized. Q1: "I like to relax and chat (emoji)" Q2: Search results
11.	P	Y	Both recognized Q1: iTunes Store Q2: "My taste in music is rather unconventional. I doubt you'd like it"	Y	Y	Both recognized. Q1: "I have been known to delve deep into discofox (emoji)" Q2: "I can say with all honesty: pretty much all of it. But some small part of me is always listening to Funkytown (emoji)"
12.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: Q2: "I'm not sure I understand"	N	P	Q1: Not recognized. Incoherent answers. Q2: Recognized. Search results (what to do with your friends)
13.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: " Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Not accurate answer: "People come from all over. That's one of the cool things about people (emoji). Q2: Search results (why do you need to learn English)
14.	P	N	Both recognized. Q1: "Interesting question". Q2: "Hmmm... I don't have an answer for that. Is there something I can help with?"	Y	Y	Both recognized. Q1: "A lot of different things. Q2: "I like learning new things."
15.	P	N	Both recognized. Q1: Search results Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Search results. Q2: Search results (a song)

Results from the IPAs Test (Participants without Speech Difficulties)

Table 11 IPAs' performance at responding to the questions¹ (Participant #1)

Siri				Google Assistant		
	Q1 ²	Q2 ³	Comments	Q1	Q2	Comments
1.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Partially. Answer: Search results Q2: Partially. Answer: Search results.
2.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	Y	Both recognized. Q1: Not accurate answer: "I live in a place filled with games (emoji). Want to play?" Q2: "There are too many to choose from but I have a soft spot for Mountain View."
3.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Answers: Q1: "I like reading recipes. They can be suspenful (emoji)" Q2: "I wish I could cook, but I always spaghet the recipe (emoji)"
4.	N	Y	Both recognized. Q1: Search results Q2: "My preferences are constantly changing. Especially when you edit them in Settings!"	Y	Y	Both recognized. Q1: "Poetry memoirs can be an interesting read". Q2: "Legal thrillers seem interesting".
5.	N	N	Both not recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	N	Y	Q1: Not recognized. Incoherent search results Q2: Recognized. "Probably February 15th 1946 when the first general-purpose computer, the ENIAC, was announced. It cost a half million dollars. That's six million dollars today".
6.	N	P	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: Search results.	Y	Y	Both recognized. Q1: "If going outdoors isn't an option, I like the idea of bringing nature inside, with some rainforest sounds to help with focus (emoji)" Q2: "Cafes can provide a nice change of environment, and drinks and snacks are always handy (emoji)"

¹ Was the question answered? 'Y'=Yes; 'N'=No; 'P'=Partially

² Questions formulated with B2-level grammar structures

³ Adapted questions

Results from the IPAs Test (Participants without Speech Difficulties)

7.	P	P	Both recognized. Q1: Search results Q2: Search results	P	Y	Both recognized. Q1: Partially. Answer: Search result (what is a TV show). Q2: "Actually, I love reality TV. It's a great way to learn a lot about people (emoji)"
8.	N	N	Both recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	P	P	Q1: Partially. Answer: Search results (10 popular uses of the Internet) Q2: Partially. Answer: Search results (Uses of the Internet)
9.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1: "Video games can be a real test for reflexes. I'm best at mobile games (emoji)" Q2: "Video games are fun (emoji)"
10.	P	N	Both recognized. Q1: Search results Q2: "I'm not sure I understand"	Y	P	Both recognized. Q1 "I kick back and have fun chatting with friends, and then try to make sure everyone gets home safe (emoji)" Q2: Checks user's Google Calendar
11.	P	Y	Both recognized. Q1: Opens music player Q2: "I'm happy listening to your music".	Y	Y	Both recognized. Q1: "Pansori musical storytelling is pretty majestic". Q2: "I can say with all honesty: pretty much all of it. But some small part of me is always listening to Funkytown (emoji)".
12.	N	N	Both recognized. Q1: "I'm not sure I understand" Q2: Q2: "I'm not sure I understand"	P	P	Both recognized. Q1. Inaccurate answer: "I have lots of friends. Like this one electric toothbrush, she's very tongue in cheek." Q2: Search results (what to do with your friends)
13.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Inaccurate answer: "People come from all over. That's one of the cool things about people (emoji). Q2: "I like learning new things."
14.	N	N	Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1: "A lot of different things. Q2: "I like learning new things."
15.	P	N	Both recognized. Q1: Search results Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Search results. Q2: Search results (a song)

Results from the IPAs Test (Participants without Speech Difficulties)

Table 12 IPAs' performance at responding to the questions¹ (Participant #2)

Siri				Google Assistant		
	Q1 ²	Q2 ³	Comments	Q1	Q2	Comments
1.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Partially. Answer: Search results Q2: Partially. Answer: Search results.
2.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	Y	Both recognized. Q1: Not accurate answer: "I live in a place filled with games (emoji). Want to play?" Q2: "There are too many to choose from but I have a soft spot for Mountain View."
3.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Answers: Q1: "I like reading recipes. They can be suspenful (emoji)" Q2: "I wish I could cook, but I always spaghet the recipe (emoji)"
4.	P	Y	Both recognized. Q1: Search results Q2: "I'm happy to go with your opinion on this one"	Y	Y	Both recognized. Q1: "Horror fiction seems interesting" Q2: "Vampire literature seems interesting"
5.	N	N	Both not recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	N	Y	Both recognized. Q1: Bad answer: "It was great, thanks! I was learning about instruments from around the world and how unique they all are. Like Germany's glockenspiel (emoji)" Q2: It was a great day when I learnt the meaning of 'dulcet'. It Dulcet is such a nice word".
6.	N	P	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: Search results.	Y	Y	Both recognized. Q1: "The library is a good pick. It's nice to be surrounded by useful information (emoji)" Q2: "Cafes can provide a nice change of environment, and drinks and snacks are always handy (emoji)"

¹ Was the question answered? 'Y'=Yes; 'N'=No; 'P'=Partially

² Questions formulated with B2-level grammar structures

³ Adapted questions

Results from the IPAs Test (Participants without Speech Difficulties)

7.	P	P	Both recognized. Q1: Search results Q2: Search results	P	Y	Both recognized. Q1: Partially. Answer: Search result (what is a TV show). Q2: "Actually, I love reality TV. It's a great way to learn a lot about people (emoji)"
8.	N	N	Both recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	P	P	Q1: Partially. Answer: Search results (10 popular uses of the Internet) Q2: Partially. Answer: Search results (Uses of the Internet)
9.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1: "Video games can be a real test for reflexes. I'm best at mobile games (emoji)" Q2: "Video games are fun (emoji)"
10.	P	N	Both recognized. Q1: Search results Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1 & Q2 "I kick back and have fun chatting with friends, and then try to make sure everyone gets home safe (emoji)"
11.	N	Y	Q1: "I'm not sure I understand" Q2: "I'm happy listening to your music".	Y	Y	Both recognized. Q1: "I'm into beats and rhymes. I found out a student at Harvard submitted a ten track rap album as his final dissertation" Q2: "I can say with all honesty: pretty much all of it. But some small part of me is always listening to Funkytown (emoji)"
12.	N	N	Both recognized. Q1: "I'm not sure I understand" Q2: Q2: "I'm not sure I understand"	P	P	Both recognized. Q1. Inaccurate answer: "I have lots of friends. Like this one electric toothbrush, she's very tongue in cheek." Q2: Search results (what to do with your friends)
13.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Inaccurate answer: "People come from all over. That's one of the cool things about people (emoji)." Q2: "I like learning new things."
14.	N	N	Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1: "A lot of different things." Q2: "I like learning new things."
15.	P	N	Both recognized. Q1: Search results Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Search results. Q2: Search results (a song)

Results from the IPAs Test (Participants without Speech Difficulties)

Table 13 IPAs' performance at responding to the questions¹ (Participant #3)

Siri				Google Assistant		
	Q1 ²	Q2 ³	Comments	Q1	Q2	Comments
1.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Partially. Answer: Search results Q2: Partially. Answer: Search results.
2.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	Y	Both recognized. Q1: Not accurate answer: "I'm staying in a server cluster, located in Silicon Valley. I have servers in Singapore, Australia, UK, Canada, France and Japan too." Q2: "There are too many to choose from but I have a soft spot for Mountain View."
3.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Answers: Q1: "I like reading recipes. They can be suspenful (emoji)" Q2: "I wish I could cook, but I always spaghet the recipe (emoji)"
4.	N	Y	Both recognized. Q1: "I don't understand" Q2: "My preferences are constantly changing. Especially when you edit them in Settings!"	Y	Y	Both recognized. Q1: "Utopian and dystopian fiction seems interesting" Q2: "Gaslamp fantasy seems like an interesting genre".
5.	N	N	Both not recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	N	Y	Q1: Not recognized. Incoherent search results Q2: Recognized. "My favorite day is September 15, 1997, the day Google.com was registered. I wish I'd been there for it (emoji)".
6.	N	P	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: Search results.	Y	Y	Both recognized. Q1: "The library is a good pick. It's nice to be surrounded by useful information (emoji)" Q2: "If going outdoors isn't an option, I like the idea ofbringing nature inside, with some rainforest sounds to help with focus (emoji)".

¹ Was the question answered? 'Y'=Yes; 'N'=No; 'P'=Partially

² Questions formulated with B2-level grammar structures

³ Adapted questions

Results from the IPAs Test (Participants without Speech Difficulties)

7.	P	P	Both recognized. Q1: Search results Q2: Search results	P	Y	Both recognized. Q1: Partially. Answer: Search result (what is a TV show). Q2: "I really like nature shows. The world is full of majestic, intelligent creatures doing cool stuff (emoji)"
8.	N	N	Both recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	P	P	Q1: Partially. Answer: Search results (10 popular uses of the Internet) Q2: Partially. Answer: Search results (Uses of the Internet)
9.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1: "Video games can be a real test for reflexes. I'm best at mobile games (emoji)" Q2: "Video games are fun (emoji)"
10.	P	N	Both recognized. Q1: Search results Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1 & Q2 "I kick back and have fun chatting with friends, and then try to make sure everyone gets home safe (emoji)"
11.	N	Y	Q1: "I'm not sure I understand" Q2: "I always enjoy more cowbell"	Y	Y	Both recognized. Q1: "I'm into beats and rhymes. I found out a student at Harvard submitted a ten track rap album as his final dissertation" Q2: "I can say with all honesty: pretty much all of it. But some small part of me is always listening to Funkytown (emoji)"
12.	N	N	Both recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	P	P	Both recognized. Answers: Q1 Inaccurate answer: "I'm friends with this calendar. We hit it off from day one". Q2: Search result
13.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Inaccurate answer: "People come from all over. That's one of the cool things about people (emoji). Q2: Incorrect search results (why you should learn English).
14.	P	N	Q1: Inaccurate answer: "Interesting question". Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1: "A lot of different things. Q2: "I like learning new things."
15.	P	N	Both recognized. Q1: Search results Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Search results. Q2: Search results (a song)

Results from the IPAs Test (Participants without Speech Difficulties)

Table 14 IPAs' performance at responding to the questions¹ (Participant #4)

Siri				Google Assistant		
	Q1 ²	Q2 ³	Comments	Q1	Q2	Comments
1.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Partially. Answer: Search results Q2: Partially. Answer: Search results.
2.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	Y	Both recognized. Q1: Not accurate answer: "You can find me on all types of devices, like phones and Google Home. Pretty sweet digs, if you ask me". Q2: "There are too many to choose from but I have a soft spot for Mountain View."
3.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Answers: Q1: "I like reading recipes. They can be suspenful (emoji)" Q2: "I wish I could cook, but I always spaghet the recipe (emoji)"
4.	P	Y	Both recognized. Q1: Search results Q2: "I'm happy to go with your opinion on this one"	P	Y	Both recognized. Q1: Partially. Search results Q2: "Graphic novels seem interesting".
5.	N	N	Both not recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	N	Y	Q1: Not recognized. Incoherent search results Q2: Recognized. "The day Google.com was registered was a pretty neat day. That was September 15, 1997 (emoji)".
6.	N	P	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: Search results.	Y	Y	Both recognized. Q1: "Cafes can provide a nice change of environment, and drinks and snacks are always handy (emoji)" Q2: "The library is a good pick. It's nice to be surrounded by useful information (emoji)".

¹ Was the question answered? 'Y'=Yes; 'N'=No; 'P'=Partially

² Questions formulated with B2-level grammar structures

³ Adapted questions

Results from the IPAs Test (Participants without Speech Difficulties)

7.	P	P	Both recognized. Q1: Search results Q2: Search results	P	Y	Both recognized. Q1: Partially. Answer: Search result (what to watch). Q2: "I love reality TV. It's a great way to learn a lot about people"
8.	N	N	Both recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	P	P	Q1: Partially. Answer: Search results (10 popular uses of the Internet) Q2: Partially. Answer: Search results (Uses of the Internet)
9.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1: "Video games are fun (emoji)" Q2: "Video games can be a real test for reflexes. I'm best at mobile games (emoji)"
10.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	Y	Both recognized. Q1: Partially. Answer: Search results. Q2: "I kick back and have fun chatting with friends, and then try to make sure everyone gets home safe (emoji)"
11.	P	Y	Both recognized. Q1: Opens iTunes Store Q2: "I'll listen to pretty much anything"	Y	Y	Both recognized. Q1: "I'm into beats and rhymes. I found out a student at Harvard submitted a ten track rap album as his final dissertation" Q2: "I can say with all honesty: pretty much all of it. But some small part of me is always listening to Funkytown (emoji)"
12.	N	N	Both recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: "Well, you're my friend". Q2: Search results (what to do with your friends)
13.	N	N	Both recognized. Q1: "I'm not sure I understand". Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Inaccurate answer: "People come from all over. That's one of the cool things about people (emoji). Q2: Incorrect search results (why you should learn English).
14.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1: "A lot of different things." Q2: "I like learning new things."
15.	P	N	Both recognized. Q1: Search results Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Search results. Q2: Search results (a song)

Results from the IPAs Test (Participants without Speech Difficulties)

Table 15 IPAs' performance at responding to the questions¹ (Participant #5)

Siri				Google Assistant		
	Q1 ²	Q2 ³	Comments	Q1	Q2	Comments
1.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Partially. Answer: Search results Q2: Partially. Answer: Search results.
2.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	P	Y	Both recognized. Q1: Inaccurate Answer: "I'm staying in a server cluster, located in Silicon Valley. I have servers in Singapore, Australia, UK, Canada, France and Japan too." Q2: "There are too many to choose from but I have a soft spot for Mountain View."
3.	N	N	Both recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Answers: Q1: "I like reading recipes. They can be suspenful (emoji)" Q2: "I wish I could cook, but I always spaghet the recipe (emoji)"
4.	P	Y	Both recognized. Q1: Search results Q2: "My preferences are constantly changing. Especially when you edit them in Settings!"	Y	P	Both recognized. Q1: "Hard fiction fiction seems interesting" Q2: "I can show you the top books for every decade"
5.	N	N	Both not recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	P	Y	Both recognized. Q1: Innacurate Answer: "It was great, thanks! I was learning about instruments from around the world and how unique they all are." Q2: "The day Google.com was registered was a pretty neat day. That was September 15, 1997 (emoji)".
6.	P	P	Both recognized. Q1: Search results Q2: Search results.	Y	Y	Both recognized. Q1: "If going outdoors isn't an option, I like the idea ofbringing nature inside, with some rainforest sounds to help with focus (emoji)". Q2: "Cafes can provide a nice change of environment, and drinks and snacks are always handy (emoji)"

¹ Was the question answered? 'Y'=Yes; 'N'=No; 'P'=Partially

² Questions formulated with B2-level grammar structures

³ Adapted questions

Results from the IPAs Test (Participants without Speech Difficulties)

7.	P	P	Both recognized. Q1: Search results Q2: Search results	P	Y	Both recognized. Q1: Partially. Answer: Search result (what to watch). Q2: "I love reality TV. It's a great way to learn a lot about people"
8.	N	N	Both recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	P	P	Q1: Partially. Answer: Search results (10 popular uses of the Internet) Q2: Partially. Answer: Search results (Uses of the Internet)
9.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1: "Video games are fun (emoji)" Q2: "I like all kinds of games"
10.	P	N	Both recognized. Q1: "Search results." Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1 & Q2 "I kick back and have fun chatting with friends, and then try to make sure everyone gets home safe (emoji)"
11.	P	Y	Both recognized. Q1: Opens iTunes Store Q2: "I mostly listen to the music of the spheres".	Y	Y	Both recognized. Q1: "I can say with all honesty: pretty much all of it. But some small part of me is always listening to Funkytown (emoji)" Q2: "I have been known to delve deep into discofox (emoji)"
12.	N	N	Both recognized. Q1: "I'm not sure I understand" Q2: "I'm not sure I understand"	P	P	Both recognized. Answers: Q1 Inaccurate answer: "I'm friends with this calendar. We hit it off from day one". Q2: Search result
13.	N	N	Both recognized. Q1: "I'm not sure I understand". Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Inaccurate answer: "People come from all over. That's one of the cool things about people (emoji). Q2: Incorrect search results (why you should learn English).
14.	N	N	Both recognized. Q1: "Hmmm... I don't have an answer for that. Is there something I can help with?" Q2: "I'm not sure I understand"	Y	Y	Both recognized. Q1: "A lot of different things." Q2: "I like learning new things."
15.	P	N	Both recognized. Q1: Search results Q2: "I'm not sure I understand"	P	P	Both recognized. Q1: Search results. Q2: Search results (a song)

Results from the IPAs Test (Participants with Speech Difficulties)

Table 16 IPAs' performance at voice recognition accuracy¹

	P#1		P#2		P#3		P#4		P#5											
	Siri	Google Assistant	Siri	Google Assistant	Siri	Google Assistant	Siri	Google Assistant	Siri	Google Assistant										
	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2										
1.	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1		
2.	N	1	N	N	N	1	2	2	N	3	N	N	N	3	N	N	3	3	1	1
3.	1	2	2	2	1	1	1	1	1	1	1	1	1	2	3	1	1	1	1	1
4.	N	1	1	1	1	1	3	1	2	N	N	1	N	1	N	2	1	1	N	1
5.	N	N	N	1	N	2	1	1	N	N	N	1	N	2	N	1	N	N	N	1
6.	N	N	3	1	N	N	1	N	N	N	N	N	2	1	1	N	N	N	N	1
7.	N	1	1	1	3	1	1	1	N	1	N	1	N	1	N	1	2	2	N	1
8.	1	1	3	2	1	N	1	2	N	1	N	1	1	1	1	1	1	1	2	2
9.	1	1	3	2	1	N	1	2	N	1	N	1	1	1	1	1	1	1	2	2
10.	N	3	1	2	2	2	1	2	N	1	N	1	N	1	N	1	1	1	2	2
11.	1	1	1	1	N	1	1	1	N	N	1	1	1	1	1	1	1	1	1	1
12.	N	3	1	2	1	1	1	1	N	1	N	1	N	1	N	1	1	1	2	2
13.	N	1	2	1	N	2	1	1	N	1	1	1	1	1	1	1	1	1	1	1
14.	2	1	N	2	N	N	1	1	1	N	N	N	N	1	1	2	2	N	1	
15.	N	2	1	3	N	N	1	3	N	2	1	N	2	1	N	N	1	1	1	1

¹ Was the question recognized? 1= Recognized at 1st attempt; 2=Recognized at 2n attempt; 3= Recognized at 3rd attempt; N=Not recognized

Results from the IPAs Test (Participants without Speech Difficulties)

Table 17 IPAs' performance at voice recognition accuracy¹

	P#1		P#2		P#3		P#4		P#5	
	Siri	Google Assistant	Siri	Google Assistant	Siri	Google Assistant	Siri	Google Assistant	Siri	Google Assistant
	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2	Q1	Q2
1.	1	1	1	1	1	1	1	1	1	1
2.	1	1	1	2	3	1	1	1	1	1
3.	1	1	1	1	1	1	1	1	1	1
4.	1	1	1	1	2	1	1	1	N	1
5.	N	1	N	1	3	3	1	1	N	1
6.	1	1	1	1	1	3	1	1	N	2
7.	1	1	1	1	1	1	3	1	2	3
8.	1	1	1	1	1	1	1	1	1	3
9.	N	1	1	1	1	1	1	1	1	1
10.	N	1	1	1	1	1	1	1	2	1
11.	1	1	1	1	2	1	1	2	1	1
12.	1	1	1	1	1	1	1	1	1	1
13.	1	1	1	1	1	1	1	2	1	1
14.	1	1	1	1	1	2	1	1	2	1
15.	1	1	1	1	2	1	1	1	2	N
16.	1	1	1	1	1	1	1	1	1	1

¹ Was the question recognized? 1= Recognized at 1st attempt; 2=Recognized at 2n attempt; 3= Recognized at 3rd attempt; N=Not recognized

FORMULARIO DE CONSENTIMIENTO

22 de enero de 2021

Se le ha invitado a participar en un Trabajo de Fin de Grado, llevado a cabo en la Universidad Rovira i Virgili, sobre el aprendizaje de lenguas extranjeras (inglés) mediante *chatbots*. Concretamente, se pretende evaluar la capacidad de respuesta y reconocimiento de voz de Siri y Google Assistant con estudiantes con y sin patologías del habla.

Esta investigación requerirá de una única sesión por videoconferencia entre los meses de enero y febrero de 2021. Por ello, realizará un cuestionario a los dos asistentes y responderá a unas preguntas. No se le grabará en vídeo ni en audio. Para garantizar la privacidad, una vez recogidos los datos de los cuestionarios, se eliminará su nombre del estudio. Asimismo, no se prevén riesgos ni complicaciones relacionados con esta investigación.

Finalmente, los resultados de este estudio se presentarán por escrito ante un tribunal de profesores para su evaluación. Sin embargo, en ningún momento se utilizará su nombre ni se revelará ninguna información que le identifique.

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Atentamente,

Alba Buendia

CONSENTIMIENTO

Sr./Sra.
participar en el estudio.

confirmando mi consentimiento para

Firma

FORMULARI DE CONSENTIMENT

22 de gener de 2021

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Estimados padres/madres/tutores:

A su hijo/a se le ha invitado a participar en un Trabajo de Fin de Grado, llevado a cabo en la Universidad Rovira i Virgili, sobre el aprendizaje de lenguas extranjeras (inglés) mediante *chatbots*. Concretamente, se pretende evaluar la capacidad de respuesta y reconocimiento de voz de Siri y Google Assistant con estudiantes con y sin patologías del habla.

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Atentamente,

Alba Buendia

AUTORIZACIÓN

Sr./Sra. _____ con DNI _____, consiento que
mi hijo/a _____ participe en el estudio

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