Gesture-Based Communication for People with Aphasia While in Bed

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Abstract: Communication is an essential part of life and, when affected, as it happens to persons with Aphasia (PWAs), it severely impacts their quality of life. Augmentative and Alternative Communication (AAC) approaches aim to aid people with their communication disabilities. However, not all parts of the day are easily covered by these solutions, e.g., when lying in bed without immediate access to them or in a state of distress that precludes reaching for one. To address this challenge, working with PWAs is key, but the communication issues affecting them might work as a barrier to obtain their contribution during the conceptual stage. To gather contributions that can work as a common ground to obtain PWAs' feedback we have been collaborating with Speech and Language Therapists (SLTs) to propose a system that allows two-way remote communication between a PWA lying in bed, alone, and other people (e.g., caregiver). Here, we describe this first stage with the SLTs leading to the conceptualization of a solution consisting of communication mediated by an assistant based on simple Yes/No questions presented audiovisually to the PWA and answered through gestures. Overall, the SLTs emphasized its adequateness and its strong potential to increase PWAs' independence.

1 INTRODUCTION

Aphasia is an acquired communication impairment, which can affect different language skills, such as verbal expression and comprehension, as well as writing and reading (Sheppard and Sebastian, 2021), having been identified in around one-third of people after suffering some type of strokes (Flowers et al., 2016).

Since verbal communication plays a pivotal role in everyone's daily life, allowing for information, feelings, and needs to be expressed, the inability to do so negatively affects our relationships and mental health due to loneliness and frustration (Holland, 2021; Sheppard and Sebastian, 2021). In this context, augmentative and alternative communication (AAC) solutions can provide support to individuals with communication difficulties, with technology boosting a wide range of proposals (Elsahar et al., 2019). Examples include several touchscreen applications based on pictograms and solutions integrating mechanical or imaging methods (Elsahar et al., 2019).

The ongoing AAL APH-ALARM project[1] aims at providing solutions that contribute to an increased sense of safety and independence for persons with Aphasia (PWAs), in different scenarios and parts of the day. In this regard, our detailed context analysis identified communication difficulties as one of the most important aspects to address. It also highlighted that existing AAC solutions are often not specifically tailored for PWAs (e.g., by being too general in content) or fail to be adequate for important scenarios, such as when the person is in bed, a scenario where communication is important (whether to ask for help when feeling unwell or for a glass of water). For example, existing solutions typically depend on a touch-based device, which may not be immediately reachable or suitable for the user's fine motor capabilities and potential level of distress; or rely on technology that is more cumbersome to use (e.g., brain-machine interfaces – BCI) or that can raise privacy concerns for the users (e.g., RGB cameras).

Furthermore, among the contributions on assistive technology, solutions to support a person lying in bed have not yet been explored, besides some work focus-

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ing mainly on gesture recognition (Guimarães et al., 2021; Guimarães, 2021; Santana et al., 2022; Santana, 2021). Supporting the bed scenario is important even for PWAs without any major motor limitation, since many are afraid to get up, during the night, in a potentially disoriented state, with fear of falling. In this regard, we aim to go beyond a simple "emergency" button towards a richer, albeit simple, communication of the PWAs' needs and concerns.

To accomplish our goals, we adopt an iterative user-centred design and development methodology to ground our proposals on the needs and contexts that might better serve PWAs. In this regard, one of the major challenges to deal with is the wide spectra of communication issues that can affect PWAs, as this works as a barrier towards open discussion and in obtaining feedback in the design stage.

When looking into how to tackle this aspect, we considered that the collection of contributions from PWAs would profit from an approach that was not merely conceptual, at first, but grounded on tangible proposals that could work as a common ground (Andersen and Mosleh, 2021). Additionally, these artifacts supporting the discussion should be chosen carefully, since they should incorporate, as best as possible, the PWAs potential needs and abilities.

To this end, we started working closely with Speech and Language Therapists (SLTs) with experience in working with PWAs, as proxies to better understand PWAs' abilities, needs and motivations, and iteratively refine a proposal that would then support the discussion with PWAs.

In this work, we describe how we applied this approach to target the in-bed scenario, as the first step of an ambitious vision of providing support in every division of the home, while starting from a place of primacy. We aim at developing a minimally intrusive system that supports the communication of a PWA, while in bed, with someone who is not present.

Considering these aims, and regarding how the PWA would interact with the proposed solution, gestures seemed a potentially viable alternative, having the advantage of not requiring the user to reach for a smartphone or buttons/switches next to the bed, or physically interact with a device while lying down and possibly in distress.

All things considered, and guided by the synergies with SLTs, this proposal is characterized by: (1) adopting arm gestures as input for the PWA interaction; (2) assisting the creation of messages to be sent by the PWA through a sequence of simple questions; and (3) providing multimodal feedback to the PWA.

2 CONCEPT PROPOSAL AND VALIDATION

To develop the envisioned system, a User Centered Design (UCD) methodology was adopted. We began by defining relevant personas and scenarios for system usage, allowing us to deepen our understanding of the target users, including their main motivations and needs, and consequently propose a concept for the system. This concept was then iteratively evolved, by being judged appropriate, refined and validated in discussions with external SLTs. The outcome of these steps also consolidated the extraction of requirements of the system.

Regarding the usage scenarios, we focused on those where the PWA is lying in bed since this is an important scenario in their daily life, due to the fact that they usually acquire Aphasia as a result of a stroke and tend to belong to an older demographic (Ellis et al., 2010). The possibility of having another stroke and not being able to ask for help is consequently a fear of PWAs. Initial feedback from SLTs collaborating in this work showed that PWAs are also often afraid of getting up at night due to the fear of falling. For these reasons, PWAs are often afraid of living alone or being left alone, which greatly reduces their independence.

Another important aspect of our proposal is the use of gestures by the PWA as input to support communication. We consider this to be a more appropriate option for the considered scenario (i.e., PWA lying in bed), when compared with other methods used in AAC solutions. For example, gestures can be performed without the need of moving around in bed to reach for a device and does not require physical interaction with a device (e.g., a smartphone or tablet with touchscreen, buttons/switches). Furthermore, arm gestures can be used even by users lacking fine motor skills. Nonetheless, the suitability of gesture input was also one of the main aspects discussed in the validation with STLs.

2.1 Persona and Scenario

Regarding the target users, our work is grounded on previous contributions by Azevedo (Azevedo, 2022) proposing a set of Personas for different profiles of PWAs and their families. From those, we selected and adapted the ones that we deemed appropriate to represent the target users of the solution proposed in the present contribution: one PWA having their speech affected, but without severe comprehension difficulties, and having a motor impairment on one side of the body; and the Persona's mother, as the potential destination of the messages sent by the PWA. The adaptation mainly targeted the Personas' motivations, to align them with the bed scenario, resorting to the literature and feedback from different professionals with experience working with PWAs.

In what follows, we present a summary of the adopted Persona with Aphasia and an illustrative scenario resulting from this process.

2.1.1 Persona – Judite

Judite is a primary school teacher, aged 38, who had a stroke leading to Broca's Aphasia (non-fluent, but retains comprehension) and paralysis on the right side of the body. She has a 11-year old daughter, Inês, and together they live with Judite's parents. Judite's biggest challenges are related with the communication with her family and being more independent. Her main motivation is to make the situation as undemanding as possible and ease the burden she feels she puts on her family.

2.1.2 Scenario – Judite Is Feeling Dizzy

Judite is resting in bed in the afternoon when she feels dizzy when trying to get up. Her parents went to the supermarket for groceries and her daughter is at school. Therefore, she activates the communication support system using the corresponding pre-defined gesture. The system asks if she needs immediate assistance, to which Judite answers with the gesture defined for "Yes". Given the answer, the system sends a message to her mother saying that Judite needs immediate help. After receiving this message on her smartphone, her mother confirms she has been notified and is on her way.

The system informs Judite that help is coming and then asks her a few more questions to better understand the context. Judite is asked if she is in pain, and she answers the question using the gesture associated with the meaning "No". She is also asked if she fell, to which Judite replies again "No". The following question is if she is feeling unwell, being answered using the gesture defined for "Yes". Meanwhile, all these answers are being given as context to her mother through her smartphone application, which helps her to better understand the situation.

2.2 Concept Refinement with Experts

To help refine our initial concept and validate the overall approach, we wanted to bring into the discussion feedback and ideas from SLTs internal and external to our research team. While it may be argued that PWAs might have been involved from the start, this possibility was dismissed due to the complexity of the condition, which may hinder the explanation of our proposal and attainment of feedback, particularly without a more tangible example. Moreover, the presentation of a prototype with potential "basic" flaws regarding, for instance, how to approach the reading and comprehension aspects, may lead to an increased sense of frustration for the PWAs, who may admit it is their fault and not an issue with the system. Therefore, we wanted to have the best possible proposal based on the SLTs' feedback, as proxy, aiming for a later and more profitable contact with PWAs.

It is important to highlight that the main focus of our work is assisting communication and we were interested in obtaining feedback with that perspective. For this reason, SLTs are the ideal source of feedback, since their focus is on communication and can offer a greater insight on the best approach and most appropriate strategies for supporting communication in PWAs' daily life.

The assessment by STLs was based on the presentation of our initial ideas in the form of a Persona and a scenario, as well as low fidelity sketches of an assistant for mediating the communication between the users of the system, which were already the result of joint work with SLTs working with PWAs, profiting from their insights. These should work as a common ground for exchanging ideas in this multidisciplinary setting, addressing a set of users with a sometimes complex condition to explain and understand, an approach that was found useful in other domains (Silva and Teixeira, 2019).

2.2.1 Method

The evaluation was performed in structured discussions with the SLTs judged adequate for conceptual refinement and validation. Two different sessions were carried out with three practicing SLTs with experience with PWAs, none of them with prior knowledge about our proposal: a first session with two SLTs, and a second session with another SLT. Both sessions also included the participation of an human-computer interaction (HCI) researcher moderating the discussion and two Computer Scientists involved in the design and development.

After a general introduction to the proposal, the following four main topics were discussed: (1) gesture adequateness for PWAs; (2) flow of communication supported by the assistant; (3) presentation of questions and feedback to PWAs; and (4) most notable motives and situations distressing PWAs in the bed scenario. These topics were intended as a high-level structuring of the session but any of the participants were free to ask further questions, share experiences, or raise other related points.

Concerning the gestures, the SLTs were presented with three gestures that were simple to perform with the hand initially resting on the mattress: *knock*, as knocking on a table; *clean*, sliding the hand horizontally; and *twist*, rotating the wrist as if handling a door knob. We asked the SLTs to rate – using a 5-level Likert-like scale, from 1 (very easy) to 5 (very difficult) – the three gestures regarding their ease to be explained to the PWA, by an SLT, as well as to be understood, remembered, and executed by the PWA, while lying in bed. We also asked for suggestions about other possible gestures.

Next, the participants were introduced to the overall idea of the assistant and its approach based on simple questions to establish the message to be sent. To further illustrate the idea and how the PWA's interaction would flow, a diagram representing the communication steps as mediated by the assistant, with examples of specific questions that might be asked in each question set, organized into three levels of priority, was used to support the discussion. We asked the SLTs about the overall appropriateness of the approach and if the proposed sequence of questions was deemed feasible for a PWA to express a need.

They were also asked about the most appropriate ways to present a specific question to the PWA, considering that three different output possibilities (text, graphics, and speech) were available. Finally, the SLTs were questioned about the needs, fears, and motivations expressed by PWAs for the in-bed scenario, to elicit a discussion leading to a first set of meaningful example questions to include and their order. The actual set of questions on the working system will be further refined by later validation steps with PWAs and might be personalized.

2.2.2 Results

There was a consensus that remote communication allows for a higher level of reassurance not only to the PWA, but also to their caregiver and relatives, reducing their constant need of checking in with the PWA. The main takeaway messages resulting from the discussions with the SLTs are summarized in Table 1 and a brief account of the rationale behind them is discussed ahead.

Gestures. Overall, the *knock* gesture was considered the best gesture, followed by *clean*, with *twist* ranked as more difficult (see Table 2). One additional gesture that was suggested for requesting help, by one SLT, was moving the hand back and forth, in the air, as if asking someone to come. This was, however, identified as more complicated to do if the person is covered, particularly if motor limitations are present.

Table 1: Summary of notable conclusions from the concept discussion with experts.

Gestures	• *Knock* and *clean* gestures approved • *Twist* gesture might be too complicated • No more than three gestures
Assistant	• Concise and short questions are essential • Organization of questions by priority makes sense
Output	• Multimodality is a must • Complement questions with available answer possibilities • Associate the answers to the gestures
Needs and Motivations	• Providing independence and reassurance would be the main motivation for PWAs and caregivers/relatives • Even a PWA with good mobility can require help at night • Specific needs and their priority were identified

Concerning the number of gestures, all SLTs recommended using no more than three gestures, but considered that two gestures would be the ideal choice for most users. Nonetheless, even for a reduced number of simple gestures, the SLTs highlighted the importance of keep the information about what features are available, at all times, to minimize the need for the PWA to remember them.

Table 2: Rating (1 - Very Easy to 5 - Very Difficult) attributed by the experts to each gesture, regarding their ease to be explained, understood, remembered, and executed. The results are the average of both sessions.

Gesture	Explain	Understand	Remember	Execute
Knock	1	2.5	2	1
Clean	1	2.5	2.5	1
Twist	1.5	2.5	3	1.5

Communication Mediated by the Assistant. The SLTs agreed with the overall idea of how the assistant obtains the information and how the needs are prioritized with the most urgent situation being the easiest to communicate. The idea of a repeated *knock* gesture leading to immediate help was also praised. Regarding the questions, emphasis was given to the need of using concise and short questions, also bringing to attention the need to minimize the number of questions that are needed to obtain relevant information on a given situation.

Multimodal Output. Regarding information presentation to the PWA, the SLTs highlighted that different ways of conveying the same message are crucial to overcome possible comprehension difficulties. In this regard, text, images, and speech synthesis should be used simultaneously. Additionally, the SLTs suggested presenting the questions available for answering along with corresponding gesture depictions (e.g., video, image).

Motives and Sources of Distress in Bed. The SLTs highlighted that even a PWA with reasonable mobility is often afraid of getting up from bed and falling — particularly during the night, affected by sleepiness, and when help is often less available —, making the system a potentially good way of dealing with several needs including: stroke; fall; getting up from bed and getting dressed; physiological needs (e.g., going to the bathroom); nutrition (i.e., eating, drinking); medication; problems concerning the bed (e.g., getting entangled in the bed covers). Some of these needs were identified as having a higher priority (e.g., fall) while others as more frequent (e.g., going to the bathroom).

2.3 System Requirements

The iterative work described above allowed the refinement of our initial concept, leading to the definition of requirements of the system for which a representative set is presented in what follows. The non-functional requirements include the following:

- Being appropriate for use in the bedroom (namely when the PWA is lying in bed), at any time of the day;
- Enabling two-way communication between the PWA and other people (e.g., caregiver, family member, friend);
- Supporting communication on the PWA's side based on a small set of gestures as input, and different redundant modes of output;
- The gestures should be easy to understand, remember, and execute;
- Being as less intrusive as possible for the PWA.

In terms of functional requirements, the following were defined:

- Providing a gesture input modality to the PWA;
- Recognizing the different pre-defined gestures, relying on sensors worn by the user and/or placed in the environment, and machine learning;
- Enabling the generation of simple messages to be sent to the other person, aided by a virtual assistant;
- Providing multiple output modalities to the PWA (e.g., speech, text, graphics), which rely on speakers and a display for presentating information;
- Providing an application that allows the secondary user (e.g., caregiver) to receive information from the PWA and send back a message.

3 SYSTEM PROPOSAL

Supported by the work carried out in the previous section, we propose a system that supports people with communication difficulties, namely PWAs, in the bedroom scenario, where the user is lying in bed alone (either resting during the day or awake during the night). The system can be described as a facilitator of communication between the PWA and other people who can be in the same home (in another division) or outside the home.

This proposal profits from previous work where methods for the use of simple arm gestures as a potential form of interaction for PWAs, making use of wearable or ambient sensors, were proposed and tested (Guimarães et al., 2021; Guimarães, 2021; Santana et al., 2022; Santana, 2021).

The current proposal, described in more detail below, introduces several important advances over the mentioned work, including: (1) addition of an assistant to mediate the communication; (2) multimodal output for the PWA (addition of text and graphics modalities); (3) adoption of a multimodal architecture based on the AM4I framework (Almeida et al., 2019). Furthermore, since this proposal already incorporates the feedback obtained in the discussions with SLTs (section 2.2), it has a greater focus on the needs of the target primary users (PWAs).

3.1 Bedroom Setup

An overview of the proposed system's setup for the bedroom, depicting the required hardware, is shown in Fig. 1. Sensors, which can be wearables or ambient sensors installed in the bed or bedroom (e.g., radar), enable gesture input by the PWA. We chose this type of sensors because they are less intrusive than other approaches (e.g., BCI) and can be used without light (as opposed to RGB cameras).

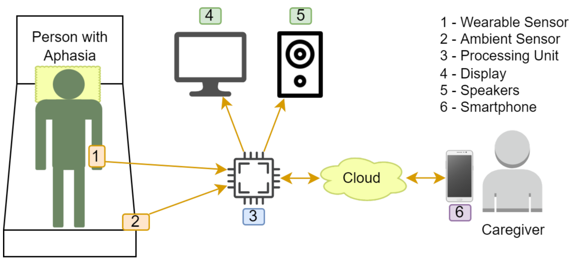

Figure 1: Overview of the setup of the proposed system for supporting communication in the in-bed scenario.

The gesture interactions serve the selection of the messages that are sent to the secondary user's smartphone. This last user is any person the PWA wants to communicate with, such as a caregiver, family member, or friend. For simplicity, this user will be considered as a caregiver for the remaining of this paper.

After receiving a message, the caregiver can send a confirmation or question using an application. That information is presented to the PWA relying on a display and speakers deployed in the bedroom. The system includes a processing unit running most of the interaction infrastructure and software.

3.2 Overall Architecture

We designed the architecture of the overall proposal having in mind not only the adoption of a general principle of modularity and decoupling among the different components, but also our vision of an assistive communication service that serves the in-bed scenario but aims to be, as already mentioned, a first step towards a broader coverage of the home.

In this context, we looked into existing approaches that might serve the integration of multiple applications, devices, and interaction options for the home environment. Among some examples, such as Mudra (Hoste et al., 2011), MIODMIT (Cronel et al., 2019), and Cue-me™ (Openstream Inc., 2015), the AM4I architecture and framework (Almeida et al., 2019) seemed to provide the desired characteristics. This framework, implementing the W3C recommendations for multimodal interactive architectures (Dahl, 2013), shows a modular and decoupled design and defines standard languages and methods for their communication, fostering easier modification and extension of the system in the future. Moreover, this framework has also been explicitly proposed to tackle interaction with smart environments (Rocha et al., 2021).

The infrastructure, the different interaction modalities available to the PWA, and the other components that enable communication support are depicted in Fig. 2. The Interaction Manager (IM) is the core module, part of the adopted multimodal architecture, and is responsible for managing the exchange of messages between the different interaction modalities and applications, ensuring their decoupling. When the IM receives a Life Cycle Event from a modality or application, it forwards it to the destination that is decided based on the relevant content.

The gesture input modality relies on data provided by the sensors to recognize the gestures carried out by the PWA. The decision based on the recognized gesture is then sent to the assistant (throught the IM), which decides the next steps, eventually leading to a message being sent to the caregiver. The latter can use the smartphone application to send a confirmation or further questions to the PWA. Since the information to/from the smartphone is sent through the cloud, the caregiver can be anywhere (e.g., another division of the same home or supermarket). All messages that have the PWA as destination are sent, through the IM, to three different output modalities (speech, graphics, and text).

3.3 Assistant

The assistant provides local feedback to the PWA and gathers information about the reason for communication before sending any message to the caregiver. This allows the PWA to know if the gestures are being detected properly. It also helps reducing the burden on the caregiver, since the assistant is responsible for obtaining most of the information from the PWA.

Three main considerations inform the design of the assistant: (1) the PWA may have different motives/priorities for communication; (2) long questions can be difficult to understand by the PWA; and (3) Yes/No answers are easier to give. Regarding communication mediation through pre-defined questions with Yes/No answers, this was mentioned by SLTs as a common approach to communicate with a PWA.

The interaction flow between the PWA and the assistant is illustrated by the simplified diagram presented in Fig. 3. When the PWA initiates communication, the assistant collects information about the reason, by navigating through a set of pre-defined Yes/No questions, which are answered by the PWA using the gestures defined for the Yes/No meaning.

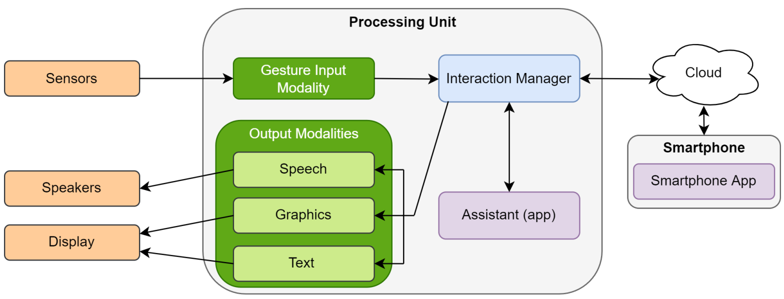

Figure 2: Infrastructure and software components that support communication.

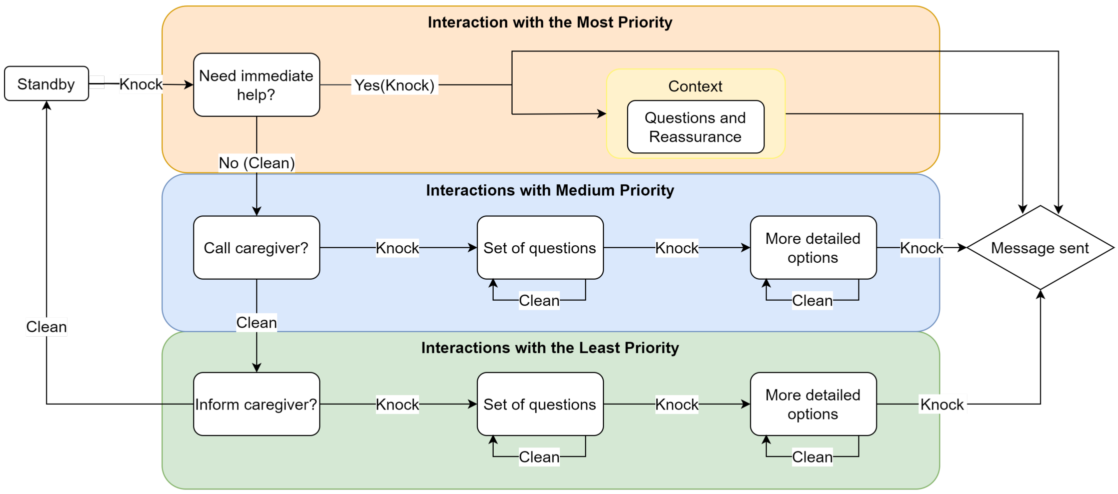

Figure 3: Simplified diagram representing the approach chosen for the interaction between the person with Aphasia (PWA) and the assistant. The three colored larger blocks represent different priorities for what the PWA may need to convey. For each priority section, a set of Yes/No questions helps gather information about the overall topic, with further details being obtained by a set of more specific questions.

To keep memorization to a minimum, only two gestures are required to navigate through the possibilities. These gestures are *knock* and *clean* (described in subsection 2.2.1), representing the “Yes” and “No” answers, respectively. *Knock* is also used to activate the system. Hence, a PWA in distress and repeatedly knocking will be able to ask for help (see Fig. 3).

The questions are organized in a hierarchy according to their priority. For each priority level — visually represented by the differently colored larger blocks in Fig 3 —, the questions look to identify the domain of the help needed among different topics (e.g., “In pain?” or “Need food?”), and further options in that domain aim at pinpointing more specific needs (e.g., “Head hurts?”, “Need water?”). To maximize comprehensibility, the questions are limited to just a verb and a noun whenever possible.

4 CONCLUSIONS AND FUTURE WORK

We proposed a new system to aid communication between a person with Aphasia (PWA) and another person (e.g., caregiver, family), for the in-bed scenario. The design of this system adopted a user-centered design approach, involving speech and language therapists (SLTs) with experience in working with PWAs.

To support this approach, we defined and iteratively refined a Persona and Scenario that served as grounds for designing the first system concept, which was then validated by three SLTs. The obtained feedback encouraged the approach taken and informed the evolution of our proposal concerning the gestures, output modalities, and questions asked by the assistant, as well as the system’s requirements definition.

The resulting system proposal includes an assistant that gathers relevant data from the PWA based on the answers to Yes/No questions. The latter are presented to the PWA using multiple redundant output modalities (speech, text, and graphics). The PWA is able to answer them using a gesture input modality, which performs gesture recognition based on a model trained using machine learning and data from sensors worn by the user.

Based on the literature and received feedback, we consider that our proposal provides features that already go beyond existing work and can potentially make a difference in assisting PWAs in their communication. This stems from tackling an important scenario, often disregarded or addressed with more intrusive technologies, and by approaching the problem with design choices that consider the PWAs’ needs and condition. This is reflected in the assistant’s mediation, question formulation, gesture choice, and multimodal output.

The implementation of a prototype of the system is already under way, including the development of a gesture recognition model, to be used in the gesture input modality, based on wearable sensor data collected from subjects while they execute the selected gestures (*knock* and *clean*) with both arms and in different postures while lying in bed. This prototype is an important step towards allowing PWAs to be involved in the discussion and thus obtaining feedback from the end users, which will be essential to develop a solution that is actually usable and useful in their daily life.

It is important to highlight that the modular architecture of the proposed system has the advantage of allowing changes to a given component without affecting the other. Therefore, if improvements are identified during validation with end users, this allows us to quickly change one or more components before the next iteration. For instance, if a different pool of gestures is suggested, we can quickly react with training new gestures and refining the gesture modality. It is also worth highlighting that the concept presented here is applicable to other contexts where gestures also make sense (e.g., sitting in a sofa), showcasing a strong potential for evolution to be explored in the future.

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