Recommendations of Embodied Conversational Agents to Healthcare Applications

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Abstract: This paper identifies recommendations for Embodied Conversational Agents (ECA) in Healthcare applications. The methodology employed consists of two systematic literature reviews in the fields of conversational systems and health care. Twenty-six recommendations for ECA were categorized into four groups: CS Interface, ECA Functionalities, Agent Behavior, ECA Customization Features, and Older Adults Engagement. Additionally, six Healthcare dimensions were identified: Interactive Learning, Disease-Specific Knowledge, Reinforcement, Emergency Detection, and Empathy/Rapport. These two sets of findings were combined for evaluation by a group of experts. The impact evaluation revealed six essential, two necessary, and eighteen desirable recommendations. The essential recommendations, derived from empirical methods, include the following: storing encrypted information, providing secure and accurate information to patients, facilitating interactive learning, allowing users to choose whether to enable proactive mode and ensuring ease of installation and use. The set of recommendations is an important contribution for ECA developers as this research presents.

1 INTRODUCTION

The use of Conversational Systems – CS in health care is not recent. The first CS was ELIZA, developed by Weizenbaum, and evolved from a simple chatbot to multimodal communication (Car et al., 2020). CS can be interactive, use active two-way communication, and use speech as a method of communication with the patient. The technology can suit various populations, ranging from young children to older people.

The use of CS can promote effective interaction, engagement, and intervention, particularly in managing chronic conditions, promoting healthy behaviour, and supporting older adults (Pradhan et al., 2020). Special Conversational Agents allow reliable and efficient information delivery and should exhibit social skills (Yang & Aurisicchio, 2021). These skills include using nonverbal behaviour to convey communicative and social signals. Ideally, agents should be able to produce and recognize nonverbal signals in simulations of face-to-face actions. Agents with such capabilities are named Embodied Conversational Agents - ECA (Barros, 2021, Bickmore & Cassell, 2005). Some features related to ECA are facial and body expressions, movement of parts, and even the use of lights and colors to promote interaction (Potdevin et al., 2021; Ruttkay et al., 2004).

From the perspective of ECA´s development, features, recommendations, characteristics, and emphatic aspects need to be related to Health Care. There are a lot of existing recommendations in Literature, but we propose a way to validate them using a questionnaire with specialists. The result is a list of recommended features to achieve healthcare support and coaching. This under-progress work is a part of PhD Thesis and intends to identify the recommendations for the use of ECA in support of hypertension treatment by Older Adults.

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The next section presents material and methods used to collect the recommendations and key aspects of Health. Section three presents twenty-six ECA recommendations grouped by their functions. The fourth section presents six key dimensions of Health Care as a parameter to combine with ECA´s recommendations. Section five shows the results of matching the two sets of Recommendations and Key Dimensions of Health found. The last section proposes future works.

2 MATERIAL AND METHODS

Two Systematic Literature Reviews (SLRs) and questionnaires were used to identify the ECA recommendations. The process was made in three steps, as shown in Figure 1.

The first Step (S1) was a SLR with the query "("evaluation of" OR "guidelines" OR "heuristics" OR "recommendations") AND ("embodied" OR "conversational Agents" OR "voice Agents") AND ("elder*" OR "senior" OR "older adults")".

The *Scopus*[1] database returned six articles, and the ACM Digital Library database, 33 articles, totalling 39 sources to be analyzed. After reading the abstracts, 29 were eliminated: 12 that were not related to the ECA in Health Care, five did not involve ECAs, 8 did not involve older adults, two dealt with text interfaces (*chatbots*), in addition to 2 repeated articles. After the full reading of the articles, five were selected, which will be summarized in the next section. The update phase included more three papers considering the actual stage of the Large Language Model (LLM), such as ChatGPT. From the reading 26 ECA Recommendations were listed to be used in Step 3.

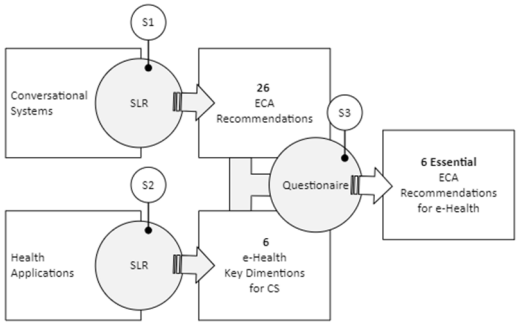

Figure 1: Steps to Identify Essential Recommendations ECA in Health Care (created by the author).

The SLR made in Second Step (S2) used the query "("e-health" OR "health" OR "telemedicine") AND ("recommendation" OR "dimension*") AND ("voice") AND ("embodied" OR "conversational Agents" OR "Conversational System" AND "older adults" AND NOT "mental health") excluding publications before 2022. Scopus returned five papers and ACM Library 35 publications. 32 were eliminated: 10 that did not involve ECA and Health Care, 12 did not present any recommendation for Health use, and obtained 8 articles. Six key dimensions were selected to play the role of evaluating each ECA´s recommendation identified.

The final step (Step 3) investigates the ECA Recommendations concerning the Key Dimensions found and their importance in achieving effective Health Care. The method used was a digital questionnaire to eight experts in Conversational System applied to e-Health. The results found are detailed in section five.

3 ECA RECOMMENDATIONS

In this work, an ECA Recommendation is a guideline related to the CS Interface, ECA Functionalities, Agent Behavior, or ECA Customization Features. Each author presents suggestions for the features or characteristics of an ECA. Six design recommendations of ECA for interaction with elderly people with dementia were extracted from EVA conversational agent from EVA conversational agent (Sandoval & Favela, 2017).

ECA LOUISE presented Alternatives to overcome the user interface restrictions linked to cognitive impairment in the elderly, making it possible to establish 14 recommendations (Wargnier et al., 2018). Eleven recommendations were identified in the results presented in a Systematic Mapping Study of Usability and User eXperience of CS (Guerino & Valentim, 2020).

There are 13 guidelines presented in a study that involves older people with dementia identified in a Voice User Interface (VUI) development (Striegl et al., 2021a). Of the 44 recommendations A total of 18 recommendations were excluded due to the repetition of features. The remaining 26 recommendations were systematically numbered to reference each type. Each recommendation is tagged according to its corresponding group: R1?? pertains to CS Interface, R2?? relates to ECA Functionalities, R3?? addresses

[1] Scopus Database. Available Sep 11, 2024, https://www.scopus.com

Agent Behaviour, and R4?? corresponds to Customization Features, with ?? representing a sequential number. The author has proposed a classification system for the recommendations within each group.

3.1 Recommendations on the CS Interface

Table 1 identifies three Recommendations for the Conversational System (CS) Interface. These recommendations are proposed by (Wargnier et al., 2018) and (Guerino & Valentim, 2020) and can be applied to most ECA for health areas or others.

Recommendation R101 refers to the need for adjustments after the first use of ECA. At this point, the input phrase should be indicated and, if possible, modified (R102). Recommendation R103 highlights the ease of use of ECA for users who are not familiar with the technology. The configurations, such as connection to the network, must be made by an initial dialog.

Table 1: Recommendations on the CS Interface.

Conversational System Interface
(R101) Simple interface, no learning required
(R102) Indicate the Agent's entry phrase
(R103) Agents should be ready to use immediately.

3.2 ECA Functionalities

Ten recommendations related to Conversational System functionalities are listed in Table 2. Recommendation R201 is related to the use of external sensors such as the User´s temperature and heartbeat, brain activities, and emotional responses from the skin. Those sensors generally reduce the usability of the equipment as they use wires to connect the users to the ECA.

Recommendations R202 - Recognize the environment of use and R203 - Recognize the user by speech (Riccardi, 2014) requires a camera and microphone connected to the ECA to assess the environment and record the user's voice. These recordings and further information must attend the R204 and be encrypted to give maximum security and privacy to the user data. Recommendations R205 - Track the user and R206 - Locate the sound source proposed by (Wargnier et al., 2018) are met when more than one microphone is installed. Sound localization in artificial systems usually uses two (or more) microphones. By the difference in the arrival times of a sound of the microphones, it is possible to estimate the direction of the sound source mathematically.

For the user to see realistic lip-synchronization movements with speech, expressive feedback in speech, and gestures, virtual agents need to use real graphical animations for the user: R207 - Introduce advanced features in avatar animation (Striegl et al., 2021).

Recommendation R208 - Provide secure and correct information is a feature linked to the base of knowledge accessed by the ECA. A (medical) team must validate the source of information. In a case of doubt, the ECA must send the issue to a human. Once the human team has defined the procedure to be taken and the answer to be given, it should input it into the knowledge base (R209: Provide learning) (Striegl et al., 2021).

The last recommendation in this group deals with storing the dialogues that have already been taken with the user. Further communication can use the previous information to provide a real human dialog. The greatest care taken with this recommendation lies in identifying true and doubtful information. The process of filtering out errors must be planned to make the result relevant (R210: Provide continuity in dialogue).

Table 2: Recommendations for ECA Functionalities.

ECA Functionalities
(R201) Recognize embedded signals (Use of sensors)
(R202) Recognize the environment of use
(R203) Recognize the user by speech
(R204) Store encrypted information
(R205) Track the user
(R206) Locate the sound source
(R207) Introduce advanced features in avatar animation
(R208) Provide secure and correct information
(R209) Provide learning
(R210) Provide continuity in dialogue

3.3 Agent Behaviour Recommendations

This group recommendation is related to the Behaviour of the Conversational Agent itself. The six recommendations are listed in Table 3 and explained as follows. The agent must incorporate the ability to coordinate and regulate emotions and understand the affective sustainability of interaction with ECA (R301: Contemplate affectivity).

To perform a (R302 Allow Sociability) “(..) Not only must a Virtual Agent be able to understand the user's emotion, but they must also be able to respond accordingly" (Riccardi, 2014). This social component is a key human skill and will be a research challenge

for human-machine interaction and possibly for machine-machine interaction (Riccardi, 2014).

Recommendation R303 - Contemplate the avatar's Behavioural reaction, established by (Wargnier et al., 2018), relates to implementing a behaviour analysis module based on recommendations R203, R206, R207, and R208 described in item 3.1.2.

Recommendation R304 - Assist the user as little as necessary refers to the ability of communicate to the user in different ways, depending on the dialog. This feature is necessary to include people who does not understand easily an instruction (Striegl et al., 2021b). The R305 Track the user's progress during the execution of a task is related to R205 but is not the same. This recommendation refers to tracking the user's body and face when executing a task.

The last recommendation of this group is R306 - React autonomously to user requests. The agent needs to be aware of a call and react not only with voice but with non-verbal activity such as a voice change or intonation.

Table 3: Agent Behaviour Recommendations.

Agent Behaviour
(R301) Contemplate affectivity
(R302) Allow Sociability
(R303) Contemplate the avatar's Behavioural reaction;
(R304) Assist the user as little as necessary, breaking down complex instructions based on the needs of the users
(R305) Track the user's progress during the execution of a task
(R306) React autonomously to user requests

3.4 ECA Customization Features

The Recommendations group related to customization and configuration are outlined in
Table 4. The first recommendation refers to the proactiveness of ECA (R401). Proactive engagement, such as medication adherence and health monitoring reminders, enhances the utility of ECAs. Interactive elements foster continuous user participation, as evidenced by studies on virtual agents like PACO and Addison Care (Krutter et al., 2022). To perform user security, the ECA must attend the R401 - provide control and adjustments in interventions from the ECA with the user. If the interventions of the ECA could be made without the Entry Phrase, the user must allow the record of all sounds around the equipment. The interventions must be realized without user command to permit a proactive comportment.

The second recommendation of this group is R402, which refers to the adjustment of personality, conversation topics, or vocabulary according to the user. This allows the user to configure the personality of the Agent, such as the way of abord themes, for example. Also, the conversation topics, in our case the Health field, and mainly a vocabulary depending on the user's level of knowledge (Guerino & Valentim, 2020). The recommendation numbered by R403 provides a way to configure different faces, voices, gestures, and embedding. Adjustment of the ECA Agent is a key to improve empathy with the user. The level of configuration starts from the gender of the agent and can be personalized to a real human characteristic. A work draws attention to the fact that the customization of the pronunciation and personality of the agent is not indicated (Guerino & Valentim, 2020).

Recommendation R404 refers to adding new character models quickly; this feature is a way to propose a known person as the agent. Recommendation R405 is about to describe interaction scenarios in a dedicated syntax. A way to guide the user to some tasks is to adopt scenarios. In this solution, the user can describe what the ECA should do to achieve a goal. For example, the user should ask the ECA to measure the blood pressure 3 times a day and inform any anomaly to medical support. The personalization of the pronunciation of the Agent voice (R406) refers to promoting different voice intonation and word pronunciation. It is remarkable when the same language is spoken in countries like Portugal and Brazil. For example, the agent's voice must be configurable to Portuguese of Portugal residents.

Table 4: Recommendations for Agent Customization.

ECA Personalization
(R401) Allows control and adjustments in interventions
(R402) Allows adjustment of personality, conversation topics, or vocabulary according to the user
(R403) Allows to configure different faces, voices, gestures, and embedding
(R404) Allows to add new character models easily;
(R405) Describe interaction scenarios in a dedicated syntax
(R406) Personalize the pronunciation of the agent voice
(R407) Set up the entry phase, response times, speed and speaking style

Besides, pronunciation is necessary to configure the tone, velocity, and other voice characteristics, such as an agitated woman's voice or an old, relaxed voice (R407). This fine configuration of the Avatar communication is fundamental to an effective human-like dialog experience. The goal is to perform comfortable and easy-to-understand communication between the agent and the user. The configuration

must be made easily, giving the user alternatives to choose or recording an example sample voice to be used.

4 HEALTHCARE DIMENSIONS

Healthcare has shown a particular interest in the use of Conversational Agents such ECA (terStal et al., 2020). To develop the ECA to support eHealth areas, it is necessary to discover mandatory ECA recommendations to achieve better patient engagement.

Technology variability of CS is related to nine aspects: devices, application technology, service channel, hosting and storage, electronic health record (EHR) integration, input/output model, intelligence framework, sentiment detection, and privacy and security (May & Denecke, 2024).

User-related variability is related to seven aspects: human involvement, care flow integration, patient profile, language and communication style, health literacy, service duration, and personal preference (May & Denecke, 2024).

The listed variables were mapped into six dimensions: Interactive Learning, disease-specific Knowledge, Reinforcement, Emergency Detection, and Empathy/Rapport.

4.1 Interactive Learning

In an Interpretative Model of Interaction by Patient-Physician (Gross et al., 2021) the Physician interprets the patient's values, and the patient decides.

Using an ECA as the physician is necessary for an **Interactive Learning (IL)** approach to engage and educate patients about health topics (Egede et al., 2021). The method should use videos, graphics, and animations to illustrate the concepts and show examples. The IL needs to be applied to Health Literacy and all engaging procedures like medicine intake, treatment procedures, alimentary suggestions, and so on.

4.2 Disease-Specific Knowledge

Disease-Specific Knowledge (SK) refers to the ECA performing accurate and up-to-date information on specific. The outcome of the health system is to provide correct information depending on the patient, based on the EHR. (Egede et al., 2021).

Some conversational systems, such as Alexa or Google Assistant, use the Internet as a source of knowledge. This dimension points to a dedicated base created by specialists.

4.3 Reinforcement

The **Reinforcement (R)** is a feature related to repeating messages over time until the goal is obtained. To follow a treatment or a medicine administration, the patient needs to be aware several times (Egede et al., 2021). Reinforcement learning is a technique involving an agent who needs to decide which actions it needs to do to perform a task that has been assigned to it most effectively. For this, rewards are assigned to the different actions that the agent can take in different situations or states of the environment.

Initially, the agent has no idea about the best or correct actions. Using reinforcement learning, it explores its action choices via trial and error and figures out the best set of actions for completing its assigned task. The basic idea behind a reinforcement learning agent is to learn from experience. Just like humans learn lessons from their past successes and mistakes, reinforcement learning agents do the same – when they do something "good," they get a reward, but if they do something "bad", they get penalized. The reward reinforces the good actions while the penalty avoids the bad ones.

Reinforcement learning requires several key components: Agent – This is the "who" or the subject of the process, which performs different actions to perform a task that has been assigned to it. Environment – This is the "where" or a situation in which the agent is placed. Actions – This is the "what" or the steps an agent needs to take to reach the goal. Rewards – This is the feedback an agent receives after performing an action.

4.4 Emergency Detection

To allow the user a way to **Emergency Detection (ED)**, which refers to the ability to recognize and respond to potential health emergencies (Sunghoon et al., 2019). Specialized sensors can detect alterations in the health state of the patient. Such sensors are electrocardiogram sensor (ECG), Electromyography (EMG), Electro dermal Activity (EDA), or Accelerometer sensor (ACC). Cameras and microphones can, otherwise, help to identify some emergencies in conversational voice systems. This feature can give the patient a way to have care even if he/she is not conscious or cannot move.

4.5 Empathy and Rapport

The **Empathy and Rapport (ER)** of a conversational system uses a psychological approach to simulate a human interaction. Features like mirroring verbal and nonverbal Behaviours, providing contextually appropriate emotional expressions, and maintaining continuity in dialogue have improved patient outcomes in medical systems(Salman et al., 2021, 2023).

5 RESULTS

To identify the essential recommendations that ECA needs to contemplate in a Health Care application for treatment support in older adults, we made an empirical study. This holistic approach can be used to deploy an ECA or evaluate an existing one. We start by matching each dimension described in Section 4 with the recommendations of Section 3. This process was made by the author and is listed in Table 5. Some recommendations did not match any Health Care Key Dimensions and were classified as General (G) ECA Recommendations.

After the match, a questionnaire was elaborated in Portuguese to identify the impact of each recommendation on each dimension. The questionnaire was submitted to 2 developers of ECA to support patients, three UX specialists, a Portuguese nurse, and experts totaling eight participants.

For each Recommendation, the participants indicate the ECA recommendation as *Unnecessary*: The recommendation does NOT need to be in the ECA to carry out activities to support the treatment of diseases for older adults; *Desirable*: The recommendation does not need to be in the ECA to achieve the proposed objectives but can somehow improve the engaging process; *Necessary*: The recommendation is fundamental and *Cannot Evaluate*: There is no consensus, or the text of the recommendation is unclear.

The main finding is that no recommendation was categorized as Unnecessary (Figure 2). This points out that, somehow, all the guidelines contribute to performing effective Health Care. The *Desirable* set was the biggest one: 70% of the total. The related health dimensions were Emergency Detection, Empathy and Rapport, and all general dimensions. Special sensors related to Emergency Detection are set as Desirable as the devices are not easy to use and install in patients. The participants wrote about the difficulties related to considering these features as a second round of testing. An effective Emergency Detection Device needs to guarantee 100% free error.

Table 5: Health Care Dimensions x ECA Recommendations x Impact.

Health Dimension	ECA Recommendations related	Impact
IL, SK, R	R204, R208, R209 and R210	*Essential*
ED	R201, R202, R203, R205, R206 and R305	*Desirable*
ER	R103 and R401	*Essential*
	R301 and R302	*Necessary*
	R303	*Desirable*
General	R101, R102, R207, R304, R306, R402, R403, R404, R405, R406, R407	*Desirable*

Another recommendation set as *Desirable* was R303, Contemplate the avatar's Behavioural reaction. The respondents complain about the complexity of non-verbal feedback. This recommendation is related to the other General Recommendations, including R402, which allows adjustment of personality, conversation topics, or vocabulary according to the user, and R403, which allows the configuration of different faces, voices, gestures, and embedding.

Although the configuration set recommendations are important to an ECA, the participants evaluate them as desirable. This fact needs to be revisited in future works to validate them.

There were two *Necessary* recommendations: R301, contemplate affectivity, and R302, Allow Sociability. They are concerned with the dialog between the ECA and the user. The Agent needs to incorporate empathic and motivational dialogues and enhance user adherence. To confirm this, empathic dialogue frameworks based on doctor-patient communication inspire design principles that make ECAs more relatable and supportive (Salman et al., 2021). The R401 is mainly about a proactive feature of the ECA.

Related to Interactive Learning, disease-Specific Knowledge and Reinforcement were identified as 4 *Essential* Recommendations. The R204 Recommendation is related to storing encrypted information and guaranteeing the ethical aspects of the health field. Recommendation R208 is as important as the previous one as it provides secure and correct information to the patient. There are no cues to errors when health treatments involve recommendation R209 to provide learning from the doctor team. The learning phase must be carefully

planned to prevent any misunderstanding in the dialog. R210 is concerned about the continuity of the dialogue. This feature is necessary to prevent the user from repeating or forgetting information.

Two essential recommendations related to empathy and rapport were identified: R103, which is related to the immediate use of the agents, and R401, which allows the user to control and adjust interventions and prevent proactiveness, for example.

6 CONCLUSION

The Recommendations encompass various aspects, including user interface design, agent behavior, and customization features, all aimed at improving user experience and engagement. The findings underscore the importance of incorporating social skills and nonverbal communication into ECAs, which are essential for fostering empathetic interactions and enhancing the overall effectiveness of these systems in healthcare settings.

Moreover, the empirical study conducted to assess the impact of ECA recommendations on healthcare dimensions highlights the necessity of aligning technological capabilities with user needs. The results indicate a set of essential recommendations contribute to effective healthcare delivery, with a significant proportion categorized as desirable (Figure 2). This suggests that while certain features may not be immediately essential, they can enhance user engagement and satisfaction, ultimately leading to better health outcomes.

The emphasis on proactive features and the ability to adjust interventions further illustrates the need for ECA to be adaptable to individual user preferences and requirements.

In conclusion, developing and implementing ECAs in healthcare represents a promising avenue for improving patient support and engagement. By adhering to the identified recommendations and focusing on user-centered design, healthcare providers can leverage the capabilities of ECAs to create more effective and empathetic interactions. Future research should continue to explore the nuances of ECA.

7 FUTURE WORK

The SLR conducted in this study reveals a comprehensive set of recommendations for the design and functionality of ECAs tailored for healthcare applications. The use of such methodology can be complemented with a LLM search to complete the study. Relating the ECA recommendations to health apps mostly involved developers and UX specialists.

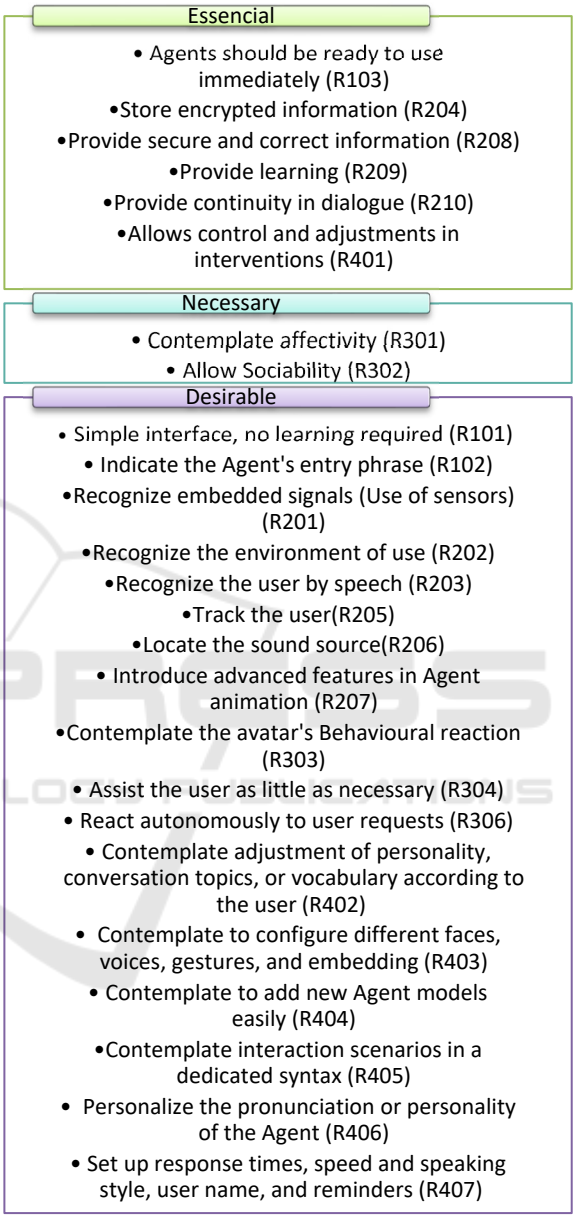

Figure 2: ECA Recommendations (by the author).

It is necessary to revisit these findings with doctors, nurses, and patients to validate all finds registered. This is the next step of the work and will be made in Portugal and Brazil with older adults.

To complete the study, it is necessary to investigate suggestions made by the respondents in the questionnaire related to section five. Some of the

participants wrote about the recommendations and the health aspects. Some related to the agent of ECA itself and some to the health issues. At this stage, the work is intended to serve as a basis for identifying the characteristics that the agent must have to guarantee user engagement with the ECA.

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