CANDY: a framework to design Conversational AgeNts for Domestic sustainabilitY

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ABSTRACT

In the 2020s, world countries are called to take action to solve global issues, as defined in the Sustainable Development Goals (SDG). In our research, we are interested in exploring how Conversational Agents can be exploited to pursue the above goals, particularly in domestic spaces where CAs are becoming more and more popular. As a preliminary step in this research work, we organized a focus group with seven participants aimed at: i) investigating the potential of Conversational Agents - integrated with digital devices - to promote a more sustainable behavior at home; ii) eliciting the requirements on conversational interaction that such CAs should meet for this purpose. From the experience and findings of the focus group, we distilled a conceptual framework called CANDY, which highlights the core design dimension of Conversational Agents for Sustainability, and can be used to guide the processes of requirements elicitation and design for this category of CAs.

CCS CONCEPTS

• **Human-centered computing** → **Natural language interfaces**; **Personal digital assistants**; *Ambient intelligence.*

KEYWORDS

conversational agents, domestic sustainability, framework, focus group

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1 INTRODUCTION

At the Sustainable Development Goals (SDG) summit in September 2019, world leaders described the 2020s as a *Decade of Action.* The meeting aimed at reviewing the 17 goals targeting world-shared issues agreed upon four years before. World countries are called to work together in building scientific knowledge and innovative tools to address the SDGs. In order to achieve SDGs, effort in accomplishing actions at global, local, and people levels is required. Modern technologies could help achieve the SDGs, and AI could play a fundamental role across different digital innovation tools. In their work, Vinuesa et al. [26] discussed AI's implications as a facilitator or an interfering factor in achieving the 2030 Agenda for Sustainable Development. In addition, they discuss the importance of managing the complexity of the interaction between people and AI systems, underling how the scientific community is reaching the turning point for the AI future.

DiSalvo et al. [7] were the first to talk about Sustainable Human-Computer Interaction (Sustainable HCI). Hansson et al. [13], starting from the previous work of DiSalvo, recently examined the paper from 2010 to 2019, mapping articles' scopes to the SDGs. The work pointed out how the current state of the research focuses on SDG number 12, which is *Responsible Consumption and Production.* This goal predicates optimizing the usage of natural resources and decreasing the global food and water waste, implementing reduction and recycling policies both at the people and industrial levels. In its scope, the HCI community is trying to use interactive technologies, particularly *Eco-feedback Systems* [13], to incentivize the sustainable usage of natural resources.

Different strategies to induce more sustainable behaviors have been explored in recent years. For example, [3, 14, 29] showed that the real-time visualization of domestic energy consumption leads to more responsible consumption, especially over long-term exposure [17]. Other works [1, 22, 29], instead, investigated the ability of persuasion techniques in HCI such as self-monitoring, advice, rewards, and gamification to lead to more sustainable behaviors.

Conversational Technologies, i.e., the set of technologies that interact with users through natural language [21, 23], are a promising interaction paradigm for *Eco-feedback Systems.* In fact, they are a widely investigated technology and are already used in many domestic environments [24, 25]. Latest research proved them to be effective for persuading users to complete tasks and customizing the interaction to the specific user, for example, with chatbots delivering energy feedback [11] or suggesting sustainable mobility [6]. On the other hand, several studies investigated the use of IoT devices in domestic spaces for sustainability [8, 9]. Yet, little work has focused on completely studying the potential of integrating digital devices and conversational technologies for sustainability in domestic spaces. To fulfill this open issue, we organized a focus group involving seven participants with different educational and working backgrounds, operating on the topic of environmental sustainability in the domestic context.

The focus group aims to answer the research question: *"Which are the potential domestic area of intervention in which conversational technologies, integrated with digital devices, could interact with*

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people for a more sustainable behavior?". Participants pointed out interesting open challenges in sustainable HCI to be considered in designing new technological tools, particularly for new conversational interfaces addressing energy consumption.

Taking inspiration from available frameworks for tangible interaction [16], IoT devices [18, 27], and conversational agents [2, 30], we schematized the result into a framework to support the design of Conversational Agents for sustainability in home automation. The tool provides designers a way to reason in the major dimensions that open in the definition of such a conversational agent in a domotic environment (i.e., home automation environment) [19].

The focus group's main take-home message is that Conversational Agents alone are not sufficient. Nowadays, especially in the domestic context, several smart devices (lights, appliances, thermostats, Etc.) are available. These devices must be interconnected in synergy to create an ecosystem that the conversational agent can leverage to induce users to more sustainable behaviors, for example, by optimizing the electrical demand with a more distributed appliances activation. Focus group participants underlined that the context and the goal of Conversational Agents for sustainability introduce new important dimensions to keep in consideration in the design phase.

2 FOCUS-GROUP

2.1 Setting and Participants

We conducted a two-hour focus group involving seven people on a voluntary basis interested in domotics and sustainability, especially from the energy perspective. Recruited participants had different backgrounds, both academic and from industry. In order to better explore the design of these conversational agents, through our network of contacts, we selected people who, through their experience (working and personal), had touched upon the topic of technology for environmental sustainability (especially from the perspective of end-user needs). The focus group addressed the potential household areas of intervention in which conversational agents, together with digital devices, could interact with people to promote more sustainable behavior. The study was conducted on March 3rd, 2022, in the research laboratory work-space maintaining all social distancing regulations for COVID-19. The participants were:

- Two Computer Science master program students;
- One Ph.D. student in Information Technology;
- One Ph.D. student in Psychology;
- Three Engineers from the Research and Development department of one of the biggest national Energy Provider companies.

Two Ph.D. students working in the Human-Computer Interaction field conducted the focus group. One of them also has expertise in Scientific Communication and led the focus group, while the other has been the observer, taking notes.

2.2 Procedure

The focus group investigated the potential domestic area of intervention in which conversational technologies could interact with people inducing more sustainable behavior. In order to explore the complex topic, the focus group was split into three activities: *Smart Home*, *Intervention Framework*, and *Product Box* described in detail in the following sections. Participants had to carry out these activities divided into two working groups, created in order to maximize the heterogeneity and the multi-disciplinarily within each group.

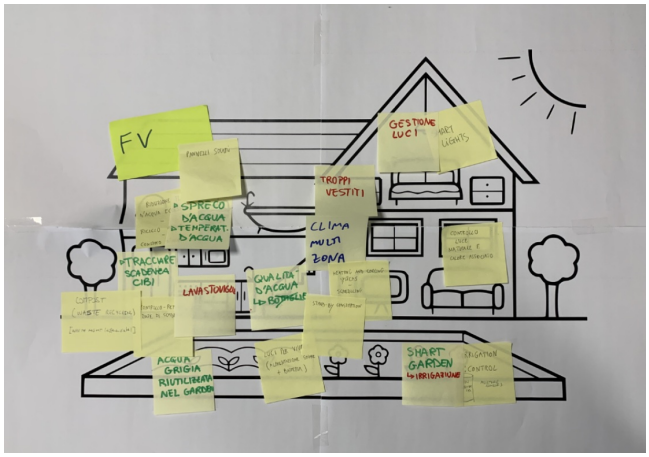


Figure 1: The home diagram with the sticky notes

Each activity is characterized by two phases, a working session in small groups and a restitution session to the room, in which the results of the first phase are presented. The activities had different objectives and execution times. Overall, the entire focus group lasted 2 hours.

2.2.1 Smart Home. The focus group's first (ice-breaking) activity aimed to identify the design space in a domotic environment to design conversational agents for sustainable behaviors.

We asked participants to think about all the possible areas in which people can intervene to increase their sustainability. The area could be identified with specific devices or furniture, such as the fridge or the tap (representing the water consumption), or structured environmental data, such as temperature, humidity, and light sensors (e.g., to have the live status of plants in the garden). During the brainstorming phase, participants could attach sticky notes on the elements over the schema of a house (Figure 1) to represent the areas of intervention graphically.

Groups had about 15 minutes to brainstorm their ideas. After that, the two groups shared the home schema and considerations about the activity with the other group and facilitators.

2.2.2 Intervention Framework. The second activity aimed to elicit the different functional design dimensions of a Conversational Agent for sustainability in a domotic environment. The participants had to create relevant use-cases (based on the sticky notes of the previous step) using a custom Interaction Framework (see Figure 2.A). The framework was created starting from an existing similar business framework to elicit application requirements.

As the first step, the framework required participants to define use-cases related to the intervention areas (and digital devices) for each house environment randomly assigned to them (reported in Table 1). Once they had defined the use-cases to focus on, they had to define the key triggering event of the CA interaction. They

Table 1: Table reporting Group members and Spaces assigned (*home rooms used to build the use-cases)

	Group members	Spaces assigned *
GROUP 1	Computer Science student	Garden and Roof
	R&D Energy Company	Bed room
	R&D Energy Company	Living room
	Ph.D. student in Information Technology	
GROUP 2	Computer Science student	Bath
	R&D Energy Company	Kitchen
	Ph.D. student in Psychology	

had to elicit the communication features of the CA, answering two facilitators' questions: *What does the CA communicate?* and *How does the CA communicate it?*. Finally, they had to specify the engagement mechanism, without designing the conversation in detail but trying to determine how to keep the user interested in the dialogue with the CA. The user must not be bored by the CA, especially considering that a specific device (associated with a use case) could be triggered more times in a day.

The use-cases definition lasted 30 minutes, followed by a group presentation of the work done.

2.2.3 Product Box. As a final activity, we wanted to explore the relevant emotional design dimension a CA should have to adapt to different possible user personas.

We asked participants to shift their attention to describe the attributes of the relationship between CA technology and people. Since the task has an inherent abstraction complexity, we facilitated the activity using *Product Box*'s game [12].

The participants had to imagine having the product designed in the previous phase of the focus group and work on its packaging. We asked them to design the hypothetical product box to be displayed on the shelves in stores. In doing that, participants had to reason on which key characteristics can persuade potential users to buy this technology and, consequentially, in its adoption.

We gave each group a plastic container they had to decorate as they wished, using white paper, tape, and markers. The creation process (divided into the working group) lasted 15 minutes, with a final presentation and discussion of the boxes.

3 RESULTS AND DISCUSSION

This section presents the results from the different phases played during the focus group. Each phase had a group work activity (about the proposed topic), followed by a sharing moment of the outcome with the other group members and the presenters. During both the phases, conductors went around the group to take notes of the activity and participants' considerations.

At the end of the focus group, material produced by the groups and observers' notes has been, revised and analyzed to summarize the results described in this section, to then be used to ground the CANDY framework.

3.1 Smart Home

The group work in the first activity generated many ideas (sticky notes), comments, and discussions about the intervention areas (or single device).

After the focus group, we analyzed the sticky notes, extrapolating two dimensions. The first is the trigger:

- *User:* The triggering event starts from the householder, interacting directly with the CA or with a specific domotic device;
- *Environment:* The trigger is a particular change of state of a device in the smart home.

The other dimension is the event type, split in:

- *Action:* An action that an agent (user or other devices) plays in the environment generates this type of event;
- *Condition:* The event is generated by a logic sum of state conditions of devices or user-generated data.

The groups found a similar number of *User* and *Environment* triggers, whereas they listed more *Actions* w.r.t. the *Conditions* (Figure 3).

During the discussion, two topics recurred the most. First, *"Conversational Agents alone are not sufficient"* to help users have a more sustainable behavior. Second, participants highlighted how essential the devices' synergy in the domotic ecosystem is – especially when used with conversational technologies.

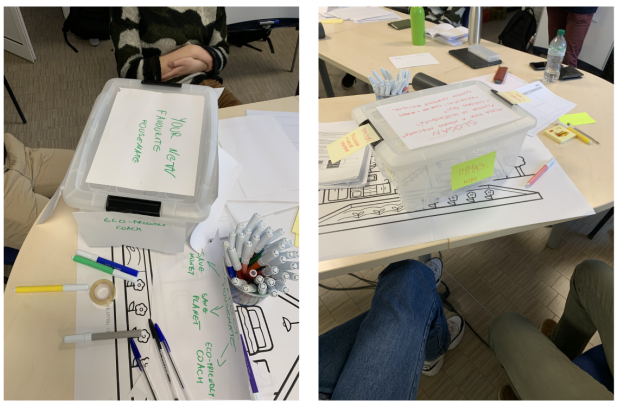
Ambient intelligence could be a fundamental tool to understand the context better and use it to target the dialogues and intercept users' actions inside the domestic environment. For example (as presented by a participant), suppose the user is loading a smart dishwasher. If the dishwasher is not fully loaded, a Conversational Agent in the kitchen could propose postponing starting the device to the next mealtime. While in case the dishwasher is complete, the CA could automatically start the device at night (when usually the energy demand is lower) with the eco-mode triggered.

Finally, device synergy could automate daily-based routines easily (e.g., controlling the lights, turning on the thermostat). As it is now, the user has to create different routines (mainly with the mobile application of the appliance provider); with device synergy, these tasks could be automated and orchestrated with a Conversational Agent that also optimizes their execution to be more sustainable.

ROOM:

USECASE	TRIGGER	COMMUNICATION	ENGAGEMENT MECHANISM
		What does the CA communicate? *How does the CA communicate it?*	

A



B

Figure 2: (A) On the left, the *Intervention Framework* template. (B) On the right, some pictures of the *Product Box* activity output

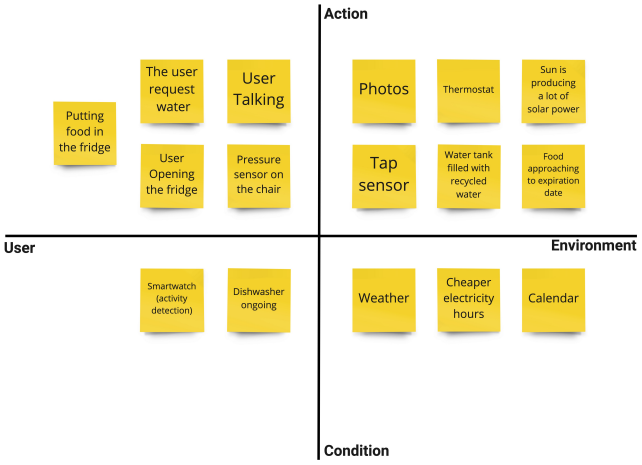


Figure 3: The classification of the sticky notes

3.2 Intervention Framework

Starting from the communication mode and the users' engagement strategies that focus group participants suggested in the second activity, we elicited aspects influencing CA's design for sustainable behaviors in domestic environments.

3.2.1 Communication Mode. Regarding the communication mode, an important feature to consider during the conversational design is the strategy adopted to act. Two main approaches have been identified during the focus group: asking the user to act or directly acting on the environment (through the digital system).

In the specific case of inducing sustainable behaviors in domestic environments, focus group participants suggested that having a CA that talks to the user should propose valid alternatives to the user instead of only asking for waivers. For example, if a device consumes too much, the CA should not just notify, asking to power it off; the CA should propose some optimization in the home (or user behavior) to keep the device powered on. When dealing with situations that can occur repetitively, such as light and temperature control, some participants suggested the conversational agent must be the least burdening possible. In contrast, other participants suggested having an acting approach (*"Act instead of talking."*) for some specific tasks to be executed in the domotic environment. Participants suggested as interesting analyzing and figuring out a Conversational technology that is adaptive to the user's day (e.g., not disturb mode when the user is on a call) and the user's behavior (e.g., slow the heating system while the user is outdoor, and turn it on before the user arrives at home).

This second feature, related to the user's behavior, is strictly related to the ecosystem of devices and deployable thanks to the recent development of IoT technologies. Another essential communication feature is the channel; participants suggested that *"everything needs its own channel."*. For example, notifications should be voice-based while the user is home; on the contrary, users could prefer chatting (i.e., text-based) with their virtual home assistants when they are not home (e.g., to turn the thermostat on before arriving home).

Yet, it is important selecting the most suitable threshold (of measure detected by the device) to trigger the conversation, avoiding falling into the over-triggered or never activated events. For example, if the system manages shower water consumption, choosing the threshold to remind the user to shorten the duration time is not easy. Worldwide, showers usually last eight minutes; how many minutes the CA starts triggering and reminds the user to finish the shower (e.g., nine minutes, ten minutes, Etc.).

Some participants believed it is essential to make users understand that *"you are not green just when you are at home."*. In contrast, others preferred to concentrate on domestic environments to maximize the efficacy in those areas. Strictly related has also been found

the theme of personal well-being, which finds some literature match in the work of Helne et al [15]. New home technologies, such as conversational technologies that want to address green objectives, should also focus on improving people's lifestyles, following One Health's World Health Organization approach [28].

3.2.2 User Engagement. Concerning user engagement, participants suggested different ways of engagement: gamification, short-term motivation, social responsibility, and 360° support. Gamification and short-term motivation have been highlighted as the easiest and nowadays used interaction strategies addressing behavioral change in people, as shown by Bang et al. [1], creating a game to inspire young people to have a sustainable attitude toward energy efficiency. Participants highlighted the importance of providing short-term motivation to keep users engaged. In literature, [10, 11, 20] suggests exploiting goal-setting to maintain it. Social responsibility and social comparison have been discussed as the challenges and motivations of the recent epoch.

A participant said: *"There is little to say; socials influence our behavior."*. In this sense, Conversational Agents must consider using social comparison and arguing using social responsibility when dealing with sustainable topics. While participants discussed engagement techniques in the home context, they also pointed out how motivation outdoors could contribute to achieving sustainability. In addition, participants suggested the OneHealth [28] approach and multi-channel communication with the user as new means to provide 360° support as a new way to keep the user motivated and engaged with the topic addressed.

Finally, participants agreed to consider how conversational technology nowadays creates engagement by saying the right thing at the right time, appearing to left unsolved how the Conversational Agent could create value in the environment. They could be the turning point in changing people's behavior in more sustainable approaches, but the impact on life and the environment could not be overshadowed.

3.3 Product Box

The monetary, environmental, and personification (and empathy with humans) aspects have been exploited as aspects that Conversational agents should leverage to persuade people to have more sustainable attitudes, to cite a slogan a group wrote on a box "brings green life to your home". The first item to leverage on is the environmental aspect. Climate change is undeniable, and a Conversational Agent must remember the catastrophic consequences of a series of damaging behaviors on the environment, especially when repeated routinely. One of the most addressed issues in the domestic sustainability case is energy consumption. Participants agreed that reducing energy consumption implies saving money (usually spent on the bill) and could be a persuasion strategy to apply to people less experienced on the topic or less willing to make sacrifices, as suggested by a team writing "Save the planet... and save your wallet". Finally, participants claimed that conversational agent personification is an important feature to consider. Virtual or not, the agent should be perceived by people as "Your new favorite housemate", as written by a group on a box. If people perceive the agent closer (as a human), they will be less apt to discard advice or requests.

Another critical aspect to consider during the Conversational Agents design is understanding the solution we deliver. Important insights from the exercise are that: nowadays, new CA technologies should address existing systems before building new ones. In addition, it is crucial to figure out from the first steps the core of the project: a product or a service. Today, producing a new product means fighting with very competitive home assistants in a closed market. Perhaps creating a new service that can be integrated with existing technologies could be the key to new *green* Conversational Agents.

4 THE CANDY FRAMEWORK

The focus group revealed several dimensions to consider in the design of conversational agents for long-term sustainability, mainly when we act in the digital home context. Starting from the insights emerged in the focus group, we produced the CANDY framework for supporting Conversational Agents' requirement elicitation and design for sustainability (Figure 5). The framework can be used to support the definition of the main feature of a Conversational Agent for sustainability. At the same time, it could also be employed in its definition in specific use cases.

Using the framework, designers can reflect on the main design dimensions of such a device: its affability, the communication with the environment, the intervention areas, and the different design dimensions.

In the first section (*Framework Part1*), the framework wants to choose the CA affability, defining inputs and outputs channels the agent can use to interact with the users. In the framework, we put general broad input and outputs. We left a blank space to let designers add other channels to fit the CA embodiment.

In the second section, the framework enters into the detail of the communication with the domotic environment to have a clear idea of the context in which the conversational agent will operate. We classify communication channels with the environment in four categories, elicited from the restitutions in the focus group (see Section 3.1):

- *User Action Sensing:* Action performed by the user in the domotic environment (e.g., the user turn on a light)
- *Environment Action Sensing:* Action generated in the environment (e.g., the solar plant is fully charged)
- *User Behaviour Sensing:* Detection of the user behavior via different conditions happening in the environment (e.g., the system detects the user is home since her phone re-connected to the Wi-Fi in the late afternoon)
- *Environment State Sensing:* Detection of particular conditions happening in the external or domotic environment (e.g., the system uses weather API to get the outdoor temperature and adjusts the thermostat accordingly)

To complete the high-level specification of the CA, designers must define the sustainability area of intervention (*Framework Part3*). For each proposed area (Energy consumption, Food management, Water consumption, and Plants), designers must decide on which level the Conversational Agent will target that area. The scale goes from Absent, in which the CA will not target the issue, to Priority, which is one of the main focus addressed by the conversational technology.

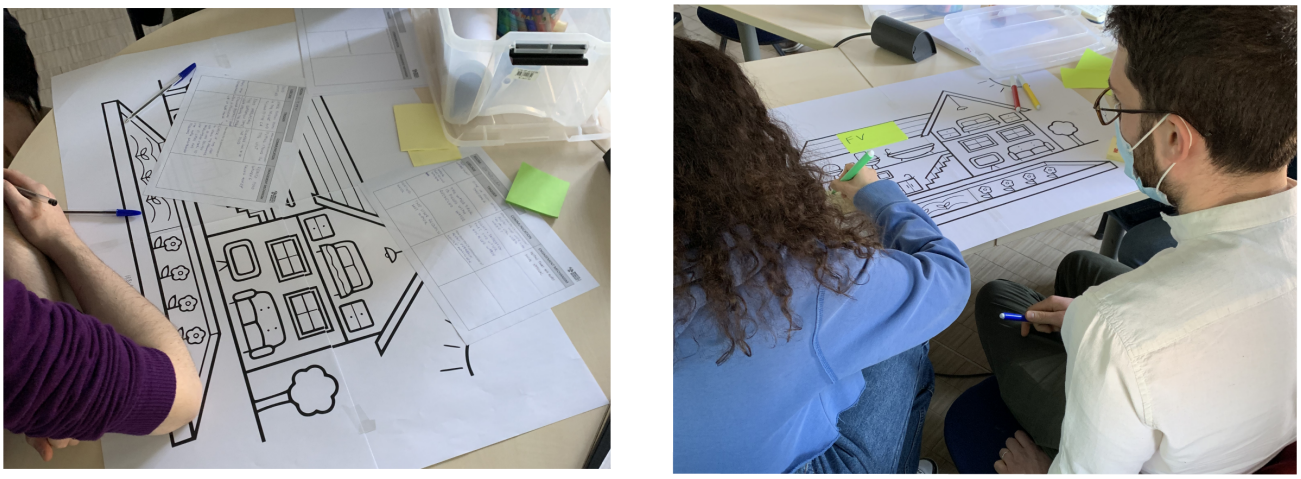


Figure 4: Participants during a group working phase of the focus group

Once the first column of the framework is complete, designers have an idea of which the communication channels will be and how the device will interact with the domotic environment. It is now the moment to focus on the interaction approach with the final users (*Framework Part4*). To support the definition of those dimensions, we list a set of dimensions designers can use to reflect on the conversational agent's behavior.

As previously stated in the literature [4, 5], our findings suggest that designers should consider how the interaction between Conversational Agents and a user occurs. We identified two main strategies: the CA could be passive and wait for a user call (hotspot word), or it could be proactive, according to some external events (e.g., some specific condition in the home) (*Framework Part4.A*). In addition, another essential feature to consider is conversational agent behavior (*Framework Part4.B*). The CA could exploit different working strategies: asking the user to perform a specific action (guidance) or directly acting on the smart environment (action), possibly without even telling the user the activity. Directly acting in a domotic environment implies having a well-integrated ecosystem of devices that work in synergy, stressing more and more the concepts of ambient intelligent and ubiquitous computing. This last point is also related to the context dimension of the conversational agent: if it should be isolated or well-integrated into the domestic environment (*Framework Part4.F*). A critical design dimension to consider is sensitivity (*Framework Part4.C*). As advised during the focus group, selecting the most suitable threshold (of measure detected by the device) is important to trigger the conversation and not be too intrusive in people's lives. When we discuss sustainability, user behavior is essential in the CA design. So, CA designers have to select the right feedback strategy: having a CA that scolds people or tries to motivate them (*Framework Part4.D*). Strictly related to the previous dimension is the intrusiveness dimension (*Framework Part4.E*). Sometimes the CA could be punctilious, while other designers prefer having a repetitive CA in giving feedback. HCI experts have to consider the personification of the technology: it could be closer to humans and let users think they are talking with a friend or being as neutral as possible (*Framework Part4.H*). In addition, the CA content presentation must be taken into account. Sometimes CA should be serious, while CA should use gamification techniques in another context (*Framework Part4.G*).

5 CONCLUSION AND FUTURE WORKS

We presented the execution and results of a focus group investigating how Conversational Agents, integrated with a digital devices ecosystem, could promote positive behaviors for environmental sustainability in domestic spaces. The focus group highlighted that conversational technology for sustainability is a complex and challenging topic to manage but, at the same time, has a strong potential to contribute to sustainable behavior in everyday life. In addition, the focus group elicited a set of design dimensions worth to be considered in the requirements elicitation and design of Conversational Agents for sustainability, especially when they are placed in the digital home context. The focus group description provides a concrete example of how to elicit design requirements for Conversational Agents in this specific domain and, together with the CANDY framework, contributes to the field of Conversational Interaction Design for sustainability.

Future steps to overcome the main limitations of our work are to test and validate the framework while designing conversational agents for sustainability and possibly evaluating it with CA experts.

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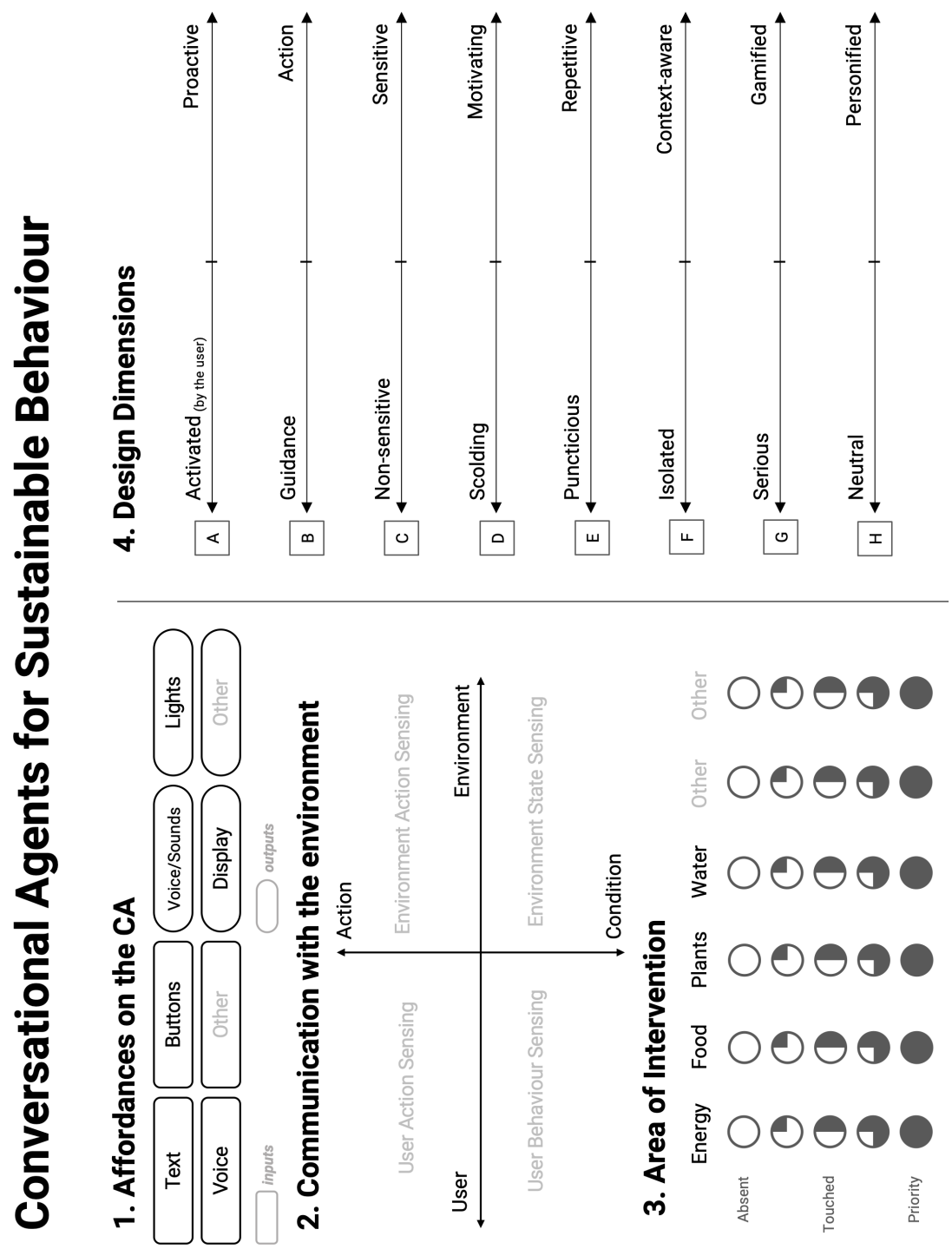

Figure 5: The Framework *Conversational Agents for Sustainable Behaviour* developed, referend in the text as *Framework*

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