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RESEARCH PAPER

Social Battery as a Design Metaphor: Crafting Wearable Devices to Share the Willingness to Socialize

Ana Gámez-Elizalde, Luis A. Castro

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Abstract

Research on personality traits and social interactions has become relevant in recent decades. Psychology research on these traits explains how different factors may influence social interactions. Work on HCI looks to augment and enhance social interactions via wearable technology. In this work, we use the emergent concept of *social battery* as a design metaphor to understand how the willingness to socialize can be crafted into a wearable device. We used the Design Sprint methodology and conducted design sessions with potential users to craft promising low-fidelity prototypes. The results of those sessions show promising directions for future development of wearables to display users' social battery.

Keywords:

HCI, Social Battery, Social Wearables, Wearables, Personality traits, Social Interactions.

1 Introduction

Research on personality traits and social interactions has become relevant in recent decades. These traits define humans as social beings with characteristic patterns of behaviors and the ability to interact with others [1]. The Five-Factor model, i.e., the Big Five, is the most widely used model to classify personality traits [2].

The Extraversion trait refers to an individual's activity level and preferred interaction. People with high levels of extraversion are classified as friendly and active, while someone with low levels is quiet and reserved [1], [2], [3]

Also, some authors explain that an extrovert ideal might exist where people with high levels of extraversion are more likely to be preferred by society [1], giving them charismatic characteristics, having preference in jobs and leadership positions, and associating them with more assertive and positive traits. In contrast, people with low levels of extroversion could be perceived negatively [4]. Personality traits play an essential role in the quality of interactions between individuals and in a person's inclination to socialize [4], [5], [6].

HCI Research has typically looked at augmenting and enhancing social interactions via wearable device design [7]. Social wearables aim to improve, facilitate, and mainly increase social interactions between individuals through wearable technologies. Their primary goal is to create a bridge between digital interactions and face-to-face interactions [7 ,8]. However, social wearables must blend with the user's personality and fashion preferences [8]. User-centered methodologies and frameworks aim to support the creation of wearable technology to include the final user in the design decisions [9, 10]. Nevertheless, most of the work done in social wearables looks to create and understand interactions between people even when a person may not desire that.

Social battery is a concept that seeks to represent one's energy to interact with others at any given moment, just as a physical battery stores energy and gets depleted with use. A *social battery* can be affected by personality, the quantity and type of social interactions, and external and internal factors [11].

Although some individuals may sense others' *social battery* levels through subtle cues, it is not always accurate. This can lead to misunderstandings [4]. Letting others know about one's willingness to socialize at a given moment could lead to pleasant, empathetic, and quality social interactions [4].

To address this gap, we propose to externalize the *social battery* through a wearable social device, taking the emergent concept of *social battery* as a design metaphor to refer to an individual's disposition towards socializing.

To achieve this, we used the Design Sprint methodology, which enables the development of innovative ideas in five days [12]. We conducted two studies to comprehensively understand *social battery* and how this concept can be implemented in wearable technology. Participants define challenges and opportunities identified to brainstorm, sketch, and finally converge to decide on the most promising solutions.

2 Related Work

In this section, we present the related work on personality traits and social interactions and how these aspects have been utilized in the field of HCI. We also discuss work on wearable and social wearable devices and their impact on social interactions.

2.1 Personality Traits

Some models, such as the Big Five Model or the Myers-Briggs type indicator [2, 13], have been used to classify users' personalities. These models assign specific characteristics depending on where the individual rates on a continuum. In the case of extraversion, people who are high in this factor are given charismatic characteristics, while those with low levels are quiet and reserved [1, 3, 13].

Some authors explain that an extrovert ideal might exist where people with high levels of this factor are preferred by society [1].

Gamez-Elizalde A., Castro, L. A.
Dept. of Computing and Design
Sonora Institute of Technology (ITSON)
Ciudad Obregon, Mexico
Email: ana.gamez.elizalde@gmail.com, luis.castro@acm.org

However, the literature suggests that personality traits do not directly influence whether a person is good or bad [1], the creativity in workplaces [14], or their capability to express their ideas [15].

Social interactions may also relate to personality traits [1, 5]. Introverts may feel tired after a long socialization period, while extroverts feel recharged after social interactions [1]. Some reports argue that people with high levels of extraversion have a better understanding of nonverbal communication than introverts [15].

Although each person might have different levels of extraversion, previous works have found that some people with low levels of this factor tend to act like extroverts. However, acting contrary to their personality traits is tiring and makes people uneasy [16].

2.2 Social Wearables

Wearable technology has made its way into people's daily lives. Applications and devices have been created to enhance wellbeing [8, 17, 18]. The underlying premise of social wearables is to augment and enhance social interactions [14]. These devices are meant to blend with the personality and user's fashion preferences [19]. These kinds of projects aim to increase social interactions [7, 8], have long-distance interactions [20], and create bonds [21].

Although some of the works mentioned above have relevant results on social wearables and their impact on social interactions, they do not include the personality traits in their measuring, taking the extrovert ideal as a starting point. More interactions do not necessarily mean higher quality interactions. Despite the work done in the last decade in HCI on wearable technologies, adopting such devices with forms other than wristbands or watches is uncommon [7, 8]. In addition, some experiments with materials other than displays, like smart textiles and conductive threads, have also been implemented [8, 22, 23].

The design of social wearable devices presents a challenge. It goes beyond merely constructing a device. These must appropriately adapt to users' preferences and personalities. It has been found that users do not want to use a screen on their clothing directly, as it alters their style and way of expressing themselves [23]. Potential solutions in the future may involve intelligent textiles that change color [24, 25], animated displays [26], interactions through conductive threads [8, 24, 25, 26], and even intelligent pigments in makeup [27]. Still, most are not readily available to users and are difficult to implement.

Other alternatives encourage form factors for wearable technologies with authentic and free shapes. Nevertheless, free-form devices must have specific characteristics for each case, fostering creativity and innovation in their design [9, 10]. In summary, the form factor of a wearable device directly influences the type and quality of interactions a person has with others. This work addresses gaps in the literature on designing a social wearable device that externalizes an individual's *social battery*, considering not only design decisions based on the users' clothing preferences but also their willingness to engage in social interactions at given moments in their day by considering potential end users.

Table 1. Study 1 Participants' Information.

Code	Age	Gender	Country	Current Rol
P1	23	Female	Mexico	Undergrad student
P2	23	Male	USA	Grad Student
P3	28	Male	USA	Grad Student
P4	24	Male	Mexico	Undergrad student
P5	21	Female	Taiwan	Undergrad student
P6	26	Male	USA	Grad Student
P7	23	Female	Taiwan	Grad Student
P8	25	Female	Mexico	Undergrad student
P9	23	Male	Mexico	Undergrad student

3 Methods

This study focuses on designing a social wearable device that visually represents an individual's level of socializing energy at various points throughout the day.

The methodology employed for this research is inspired by the Design SPRINT [12] framework, which is structured into five stages spread across five days of the week (i.e., from Monday to Friday). However, for this study, we made minor changes to the methodology. Specifically, we used some of the proposed stages but conducted separate studies with different participants. The five stages were divided into two studies (further details below) and focused on activities that would provide the most information for our research.

We next describe each study:

- **Study 1 - Brainstorming Sessions:** We held two online brainstorming sessions to gather requirements for our social wearable device, lasting about two hours each. These sessions were based on activities proposed on Day 1 and Day 2 from the Sprint Design Methodology.
- **Study 2 - Design Workshop:** We held an in-person workshop to make design decisions and craft prototypes based on the activities proposed for Day 3 and Day 4 on the Sprint Design Methodology. Participants were students from various majors from a public university in Northwest Mexico.

4 Study 1: Brainstorming Sessions

The objective of this study was to understand and define the main requirements that need to be addressed when designing a wearable device that externalizes an individual's disposition to socialize at any given moment. Some tasks from Day 1 and Day 2 of the Design Sprint methodology were selected to achieve this. These activities were conducted through remote sessions using the collaborative tools Google Meet and Miro.

4.1 Participants

We recruited nine participants (four female) aged 21 to 28 years (Mean age = 24, SD = 2.0615). Participants were from three countries (Mexico, USA, and Taiwan), diverse academic institutions, and various levels of study, including 3 PhD students, three master's students, and three bachelor's students. All participants were either computer science or Human-Computer Interaction (HCI) students. All participants were asked to sign an informed consent.

Participants shown in Table 1, were recruited via email and direct messages on the LinkedIn platform.

4.2 Procedure

We conducted two online design sessions. The first author conducted Each design session with four and five participants per session, respectively. The sessions were held using the Google Meet platform. Each session consisted of the following:

- **Introduction (10 min):** The study began with a brief explanation of the emerging concept of social battery, the research premise, and the goals of the sessions. We gave participants access to the "Official Five-Day Design Sprint Template" on Miro's collaborative platform. We chose this platform to facilitate collaborative participation among the participants, offering tools for developing the proposed session activities. The template outlines the workflow of the Sprint methodology, including activities for each day.

- **"How Might We" questions activity (10 - 15 min):** We gave participants 10-15 min to individually brainstorm "How might we?" questions, which are a way of reframing problems into positive and future-oriented design opportunities.
- **"How Might We" questions discussion (10 min):** Participants shared their questions, adding comments on the issues they arose from.
- **Sketch activity (30 min):** To translate their questions into ideas, we asked participants to sketch to explore ideas and solutions.
- **Sketches discussion (25 min):** At the end, participants shared their ideas and drawings. The participants then discussed the sketches and voted for the most promising ideas.

4.3 Data Collection

The brainstorming sessions were recorded using OBS (Open Broadcaster Software)[1]. Participants were asked for consent to record the sessions, comments, and discussions. The "How might we?" questions and sketches created by the participants were collected by saving a copy of the template in Miro. The demographic data of the participants were collected using a Google Sheets spreadsheet.

4.4 Data Analysis

We verbatim transcribed the comments and discussions of the participants using the videos. Then, we created an affinity diagram [12] using all the "How Might We?" questions. We wanted to identify patterns among the participants' opinions. The questions and themes most frequently repeated among participants were selected and condensed into a table, along with the participants' comments. Finally, we also collected the participants' sketches and transcribed their comments on the designs.

5 Study 1 – Results

This section presents the results of the Study 1. First, we present the affinity diagram obtained. Then, we present concrete findings from the session, which we call design insights. Finally, we also present their sketches and low-fidelity prototypes.

5.1 Affinity Diagram

We grouped and obtained insights from the "How Might We?" questions, which we organized into categories. This helped identify emerging patterns and focus the discussion on specific areas. We identified six categories from frequent participant questions (see Figure 1). The resulting categories are: (1) Users, (2) Social Battery, (3) Device design, (4) Privacy, (5) User acceptance, and (6) Emotional data.

We found patterns among the questions posed by most participants. For instance, some questions focused on how the social battery could be measured, how the wearable device could be designed according to user preferences, how data could be collected, how user privacy would be ensured, and the functionalities of the device, among others.

5.2 Design Insights

The affinity diagram and the emerging categories allowed us to identify common patterns and concerns. The most frequent questions among participants were reformulated as design insights to consider for wearable device design: Measurement of the social battery, device design, data collection, and quality assurance. Our participants' comments are shown in Table 2.

- **Measuring social battery:** One of the most recurring topics among participants (8 out of 9) was how the social battery would be measured. P1 and P5 concluded that one of the questions to ensure the prototype shows social battery information is "*How do we ensure that we are measuring correctly and the right thing?"* P2 added that it is also important to consider external factors affecting energy levels, "*Aside from how much users interact with other people and what are their internal traces, some other external factors such as if you drink alcohol at least I get more sociable*." Participants highlighted the importance of capturing the right indicators and considering external factors.
- **Wearable design:** Some participants (9 out of 9) mentioned that the shape, design, and what is displayed on the device are fundamental for it to be accepted by users. P2 also noted that the product should not be targeted at one type of personality, "*I think that this device should work with not only introverts but also extroverts."* Participants emphasized that the device should adapt to diverse personalities, accommodating introverts and extroverts.
- **Ensuring Privacy:** One of the most common concerns among participants (5 out of 9), on which they agreed, was ensuring data privacy. P6 mentioned that they would not like everyone to know about their current state, "*How are we going to respect others' needs for privacy? Yes, I'm okay with sharing my social battery, but that doesn't mean that I want to let everyone see it."* On the other hand, P3 mentioned, "*How can we actually ensure that the user's privacy is protected while measuring the social battery and it is not revealing information to others?"*

5.3 Sketches

Participants used the questions and discussions from the "How Might We?" phase as a basis for sketching wearable device prototypes. The prototypes proposed by participants were diverse, ranging from wearable devices made with intelligent materials, mobile applications, mobile phone plug-ins, and avatars that provide information about your *social battery* status. These sketches also addressed topics such as data collection and privacy. Sketches are shown in Figure 2.

[1] https://obsproject.com/

Figure 1. Affinity Diagram.

Table 2. Participants' comments obtained from Study 1.

	Measuring the social battery	Wearable design	Ensuring Privacy
P1	*How do we ensure that we are measuring right and the right thing with the prototype?*	*How to have the best user experience possible.*	*At this time we are all paranoiac... We have to think deeply on how to ensure privacy.*
P2	*What external factors may affect the "social battery" levels... Some other external factors such as if you drink alcohol at least I get more sociable.*	*I think that this device should work with not only introverts but also extroverts*	*How can we blend this to our existing social norm or how does that affect our social interactions and define a new social norm?*
P3	*How can we integrate the social battery measurements into existing applications and how can ensure that the measuring is correct and it is information that we can use.*	*How can design the product that can ensure the metrics, the measurements without being intrusive with the users.*	*How can we actually ensure that the user's privacy is protected while measuring the social battery and it is not revealing information to others.*
P4	-	*How can we make the wearable in a way that people want to use it without having to tell them to use it every day. What form should it have?*	-
P5	*How can we know that what we are measuring is right? First we have to know what we are feeling... So if we don't know this we won't know what our social battery levels are.*	*Another thing that I'm thinking of is how we should express our social battery levels...*	-
P6	*How do we correctly reflect our social battery? How do we know what my social levels are? I don't think that a number could effectively reflect that because maybe a 4 for me would be a 6 for other people.*	*How do we understand other people's social battery not only on a device but also in something like an app?*	*How are we going to respect others' needs for privacy? Yes, I'm okay with sharing my social battery but that doesn't mean that I want to let everyone see it...*
P7	*I think it is really important to define how to measure and show the social battery... for me I can swing from a hundred to zero and I think that has to be accurate for all the people using the device.*	*One of my questions is about is how the visual representations might reflect your social battery immediately... Another thing I'm thinking about is how to make the manifestation of social battery in a way that it doesn't look like I'm a person who is difficult to be along with.*	*You want to show people how you can socialize right now. That doesn't mean that you want to pour your heart out for them.*
P8	*I think it is very important to know how to measure the emotions and feelings of the user.*	*How should we decide the right size?... how can we make it attractive for the user.*	-
P9	*Another thing that I was thinking about is how we can consider or ignore other emotions that might be confused with social battery emptying.*	*How can we adapt the design to all the different people or personalities? What I mean is, I'm a quick charge person. If my battery ever goes down or low I can go to a quiet place to recharge myself and go and go and go but I understand that other people might be different from me. So how can we adapt the device taking that in mind.*	-

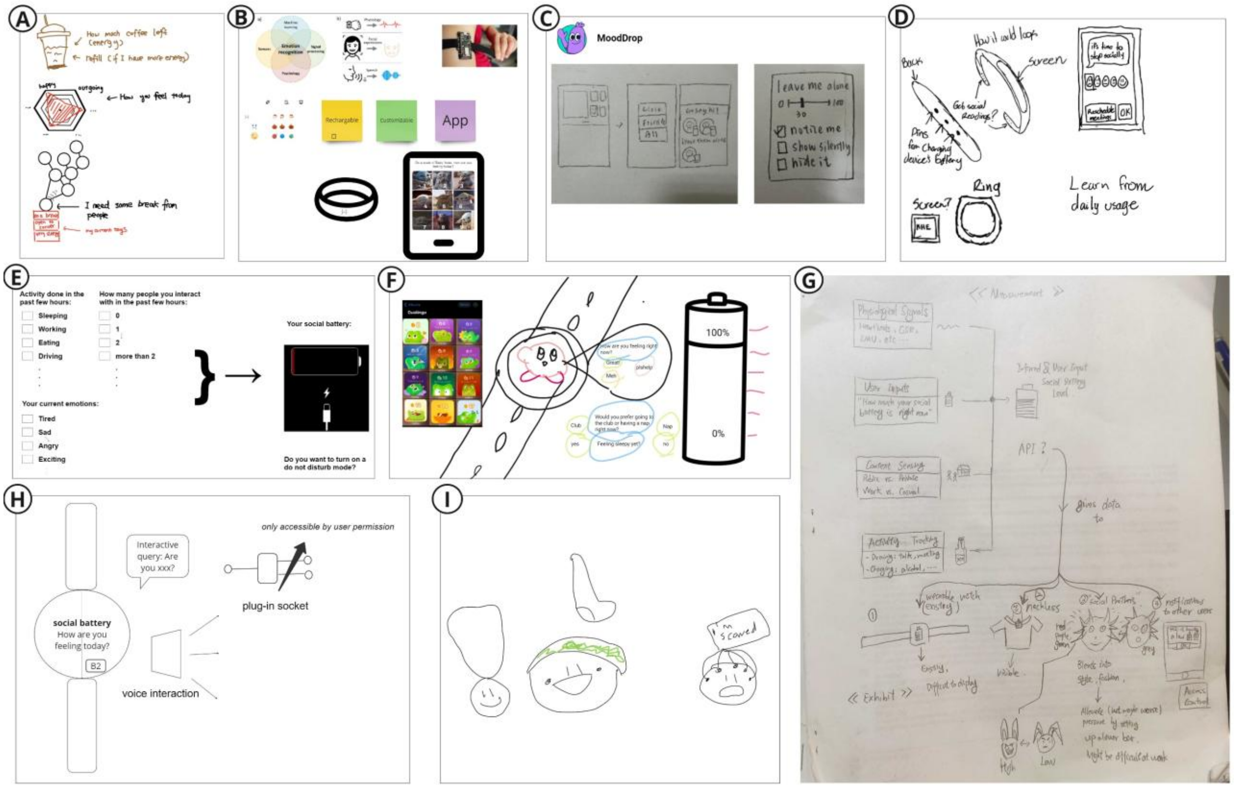

Figure 2. Sketches created by participants

6 Study 2: Design Workshop

This study aimed to develop medium-fidelity prototypes, considering the "How Might We...?" questions, comments, and sketches resulting from Study 1. We decided to recruit local students to develop adequate design alternatives for Mexico. To achieve this, an in-person crafting workshop was conducted using art materials (see Figure 3). The session lasted approximately two hours.

Table 3. Study 2 Participant Information.

Code	Age	Gender	Major
S2_P1	18	Male	Software Engineering
S2_P2	19	Female	Mechatronics Engineering
S2_P3	20	Male	Mechatronics Engineering
S2_P4	19	Male	Mechatronics Engineering
S2_P5	19	Male	Mechatronics Engineering
S2_P6	20	Female	Mechatronics Engineering
S2_P7	18	Female	Early Childhood Education
S2_P8	17	Female	Early Childhood Education
S2_P9	18	Female	Civil Engineering
S2_P10	20	Female	Electronics Engineering
S2_P11	25	Male	Industrial and Systems Engineering
S2_P12	20	Female	Tourism Business Administration
S2_P13	24	Male	Graphic Design

6.1 Participants

We made a promotional poster to diffuse the crafting workshop and added a QR code to the registration form. Participants were selected via confirmation email at a public university in Northwest Mexico. The design session was led by the first author of this article and two fellow master's students. All participants signed an informed consent. Table 3 displays the participants' information.

6.2 Procedure

The session consisted of:

- **Introduction (35 min):** It began with a brief explanation of the research context, the results, and feedback from Study 1, emphasizing the contributions and findings of the participants regarding the device design. Before starting the activities, the participants were briefed on the study's goals.
- **Sketching (25 min):** Participants were asked to brainstorm and sketch their ideas on their own on a white sheet of paper (Figure 3). They had access to art materials to enhance their creativity.
- **Idea Discussion (10 min):** Afterward, participants were instructed to randomly gather into six groups (2-3 members each) and discuss their ideas collectively.
- **Prototyping (60 min):** The next activity involved creating a medium-fidelity prototype based on previously shared ideas. Subsequently, participants shared their prototypes, explained their ideas, and received feedback from other participants.

Figure 3. Participant's ideas and materials.

6.3 Data Collection

We video-recorded the workshop to capture discussions, comments, and actions among the participants. We also took photos of the participants engaging in activities and their sketches and prototypes. Audio recordings were made of the prototype presentations.

We collected the sheets where the participants created the sketches and medium-fidelity prototypes. The demographic data of the participants were compiled into a Google Sheets spreadsheet.

6.4 Data Analysis

First, the sketches and ideas captured on the sheets by the participants were digitized. Then, photos of the medium-fidelity prototypes were taken, and the functionalities mentioned by the participants in the videos and audio recordings were added. Additionally, comments about each prototype were included.

7 Study 2: Results

This section presents the prototypes crafted by each group.

A. **Tamagotchi:** Participants presented their prototype as a Tamagotchi, where the character is customizable, and it is this character that displays the user's mood and current *social battery*. The character is more vibrant when the energy level is high. Both the character and the background are customizable. This prototype presents information about social battery levels in a fun way. On the other hand, it might give the impression of being a game rather than a visualization. Figure 4a shows the prototype.

B. **Snoopy Scale:** This involves a pin containing a customizable character or avatar, in this case, Snoopy from the comic strip *Peanuts*. The pin can be worn on clothing, backpacks, or accessories, as shown in Figure 4b. The pin is interactive; the character asks questions to gauge the person's state and willingness to interact with others. Through these questions, it defines the *social battery* level and displays it with character interactions. If the user wants to socialize, the Snoopy character dances; if not, it remains calm. It can connect to a mobile app to display information to the user. Since this prototype is a pin, it is easy to carry and use. However, the characters displayed may not accurately represent the social battery levels.

C. **Necklace:** This prototype is based on a necklace the user can customize to match their style. The users answer a series of questions via a mobile app, and based on the responses, it illuminates according to the social battery level determined by the application. Being a necklace makes it easy to carry and use. On the other hand, the information displayed might be difficult to interpret. Figure 4c shows the prototype.

D. **Locket:** It consists of a necklace with emoji charms that change according to the *social battery* level, along with motivational phrases inside for the wearer. In direct contact with the skin, the necklace chain measures the *social battery* level, which sends the signal and information to the charm. This prototype has the advantage of being comfortable and easy to wear. However, the social battery levels would be difficult to see. Figure 4d gives an illustration of the prototype.

E. **Alien:** This prototype consists of two devices: a keychain and a desk ornament. The device changes its light color depending on the individual's social battery levels. The keychain can be carried everywhere, while the desk ornament can be placed at a fixed location. Practical, simple, and portable. However, social battery levels may not be noticeable in well-lit situations Figure 4e shows the prototype.

F. **Cat:** This prototype consists of two parts: a plush cat that, when hugged or in prolonged contact, changes color to reflect the person's state, with the cat's color representing the *social battery*. Additionally, a ring with a pulse sensor determines the user's *social battery* level using heart rate data. The level of *social battery* is represented by color, and the information is sent to the plush cat. This prototype has the advantage of being visually appealing and distributing functionalities across different devices. However, plush toys tend to be large and heavy. Figure 4f features the prototype.

8 Discussion

This section highlights findings from the Brainstorming sessions (Study 1) and the Design workshop (Study 2). The Sprint Design methodology facilitated collaboration and innovation among participants, enabling user-centered ideas to be translated into wearable technology concepts. Despite having different academic backgrounds, participants converged on ideas, priorities, and concerns, leading them to suggest insights to consider in developing social wearable devices. Likewise, they were able to identify and define challenges such as data privacy and user acceptance. Through the design sessions and workshops, several significant insights and patterns emerged that are crucial for developing and accepting such devices.

One of the concerns for this work was the adaptability and usability of the device. Since it is a wearable device designed to foster social interactions according to the user's needs, it must adapt to individual preferences. The involvement of participants from various academic backgrounds and levels of study enriched the design process. The diverse perspectives contributed to more and innovative solutions, highlighting the importance of interdisciplinary collaboration in the development of wearable technology.

The following themes were identified as important considerations for developing the wearable device: Measurement of the social battery, Wearable Design, and Privacy.

Finally, the workshops provided valuable insights into user preferences and creative ideas for wearable devices. The prototypes developed were from traditional wearables like necklaces and pins to more interactive and playful designs like Tamagotchi-inspired characters and plush toys.

Our work has several limitations. For instance, Study 1 could benefit from a larger sample size. Also, our participants were from computer science or Human-Computer Interaction (HCI) fields, potentially limiting generalizability. The short duration of design sessions and workshops might have restricted participant

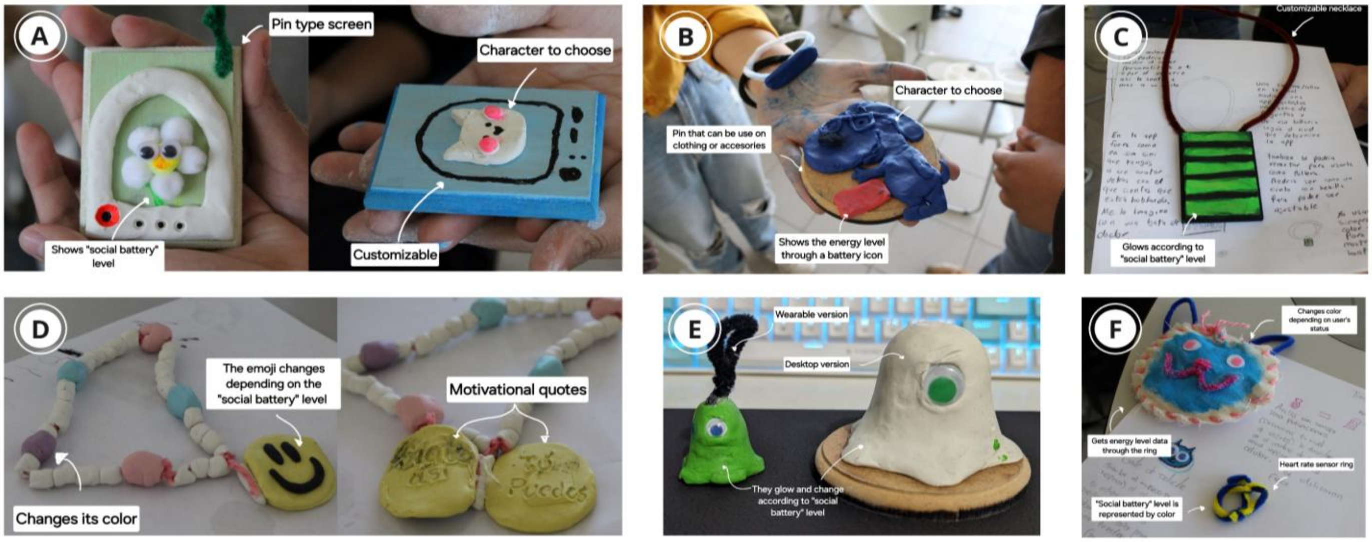

Figure 4. Prototypes: Tamagotchi (A), Snoopy Scale (B), Necklace (C), Locket (D), Alien (E), and Cat (F)

interactions and discussions. Finally, low to medium-fidelity prototypes may not fully represent the design insights shown in Study 1.

9 Conclusion

Social wearable devices are rapidly integrating into our daily lives, making it crucial to generate quality interactions. In this study, we adopted the emerging concept of *social battery* to represent an individual's disposition and energy for social interactions, aiming to design a wearable device that externalizes it. Through the Sprint Design methodology, we explored the design space.

Our initial study revealed the primary concerns for device development, which were transformed into design insights. Sketches demonstrated various ways to visualize the level of social energy through wearable technologies. Subsequently, our design workshop enabled the development of medium-fidelity prototypes based on the previously established design insights. Our work opens the way for developing wearable devices tailored to users' socialization preferences, moving away from the extrovert ideal.

Future work includes conducting a mixed study to evaluate college students' acceptance of the prototypes and their perception of the social battery concept and its effect on them. Also, we are developing a high-fidelity prototype and evaluating it with users in a wild setting.

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