Investigating Social Sensemaking Technologies for Emotional Wellbeing of Stroke Survivors and Caregivers

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Stroke survivors experience a wide range of sequelae that significantly change their lives and those of their caregivers. These changes affect relationships, professional life, and daily routines, leading to emotional distress for both. However, existing research in HCI has predominantly focused on physical and cognitive rehabilitation, neglecting the impact of stroke on emotional wellbeing. Our work explores the potential of social sensemaking technologies to support wellbeing awareness and reflection of stroke survivors and their caregivers. We developed Emotions2Us, an interactive ambient display designed to foster interdependent communication, expression, support, and reflection on emotional wellbeing among dyads. We contribute with qualitative findings from a four-week field deployment (N=8). We present an analysis of the themes that emerged from interviews with stroke survivors and caregivers, highlighting the impact of Emotions2Us on wellbeing practices and reflecting on the challenges, benefits, and opportunities of designing for social sensemaking following a stroke.

CCS Concepts: • **Human-centered computing** → **Collaborative and social computing devices**; **Empirical studies in collaborative and social computing**; **User studies**; **Displays and imagers**; **Collaborative interaction**; • **Applied computing** → *Health care information systems.*

Additional Key Words and Phrases: Stroke, Wellbeing, Emotional Wellbeing, Social Sensemaking, Caregiver

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1 Introduction

A stroke is caused by a disruption of blood supply to the brain, resulting in the death of a localised area of brain cells. With over 80 million stroke survivors globally, it is the leading cause of long-term disability worldwide [37, 61, 82, 86]. The number of people affected by stroke is rising globally [37], and its incidence is expected to increase due to an ageing population [51]. Although a stroke can impact cognitive and motor abilities, it often leads to abrupt lifestyle changes such as becoming homebound, unemployed, dependent on others, being the target of medical interventions, and

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adjusting daily routines [50, 52]. These factors significantly affect the overall wellbeing of stroke survivors [35, 102].

The concept of wellbeing encompasses not only physical and cognitive aspects but also emotional and social. Wellbeing is a state in which the individual is healthy and happy, with positive emotions and the absence of negative feelings and emotions [1, 30, 72, 85]. Social wellbeing is especially important in the context of stroke, as spouses (or other family members) often assume the role of caregivers, leading to significant adjustments in interpersonal dynamics and emotional reactions [16, 35, 79, 102]. Still, prior work in technologies for stroke survivors mostly focuses on designing novel tools for physical and cognitive rehabilitation [25, 27, 31, 34, 62, 65, 77, 88, 109, 120] despite the profound influence of wellbeing in all facets of life (including rehabilitation).

Personal wellbeing tracking is crucial for survivors to actively understand, reflect upon, and manage their wellbeing [12, 16, 79, 102]. Nevertheless, data related to wellbeing are easily overlooked or disregarded. Technological trackers such as wearable devices (e.g., Fitbit) can measure physical activity but do not consider the emotional and social dimensions of wellbeing. Additionally, they fail to consider the social context of stroke survivors. Informal caregivers, herein referred to by caregivers, as one of the key stakeholders in the survivors' wellbeing, are not only motivated and appropriate to provide help but are also affected by the stroke. While caregivers have a significantly different experience from stroke survivors, the shared experience can become valuable in driving awareness, mutual understanding, peer support, and behavioural change. However, few studies have examined how stroke survivors make sense of their wellbeing, and even fewer have included social aspects in this process [16, 79, 102]. This presents an opportunity to investigate the potential of technologies in supporting individual and social sensemaking about wellbeing following a stroke. Social sensemaking means gaining awareness of others' wellbeing states, interpersonal communication, and joint decision-making [127]. Notably, social sensemaking involves caregivers' labour, which may go unrecognised or undervalued [8, 68]. Caregivers also face significant emotional burdens, which contribute to emotional labour as they regulate and manage their emotional expressions in the context of providing healthcare services to stroke survivors [7, 54]. Social sensemaking technologies have the potential to make the labour of care visible and accountable.

In this paper, we investigate the potential of technology to mediate social sensemaking and support stroke survivors and their caregivers in enhancing their awareness and reflection on emotional wellbeing. We developed Emotions2Us, an interactive ambient display (Figure 1) designed to foster communication, expression, support, and reflection on emotional wellbeing among dyads of stroke survivors and caregivers. The design is grounded on constructivist perspectives in Human-Computer Interaction (HCI) [13] as well as the sociology of health [114]. We approach wellbeing as a social construct, meaning one's understanding of wellbeing is the product of interactions with others [89, 99]. We encourage these interactions through an interdependent design, as both survivors and caregivers must engage with the prototype to leverage its display. We aim to address three research questions: (1) Does Emotions2Us facilitate the expression of emotional wellbeing? (2) What is the influence of Emotions2Us on wellbeing awareness and social sensemaking? and (3) Does Emotions2Us contribute to the dyad's care and support practices?

To answer these questions, we deployed Emotions2Us for one month in eight households. We captured interactions with the prototype and observed emergent wellbeing-related interaction patterns of the dyads through three joint semi-structured interviews. The first interview was conducted before deployment, the second after the one-month deployment, and the final interview was conducted a week after the prototype was removed from the dyads' house.

Findings show that Emotions2Us promoted emotional state awareness between survivor and caregiver, encouraging communication between dyads about their thoughts, feelings and emotions, emotional expression and potential behaviour change. In addition, findings highlight its influence

Fig. 1. The Emotions2Us prototype consists of a smart lamp and a seven-button keyboard.

on the dyads' coping mechanisms to maintain their emotional wellbeing and show how social sensemaking technologies can support multiple stakeholders in mutual emotional care and support. Also, the dyads emphasise the potential of sharing emotional states with health professionals.

The key contributions of this paper are: (1) the design and development of Emotions2Us, an ambient display designed to enhance and support interdependent interactions and foster social sensemaking, (2) a comprehensive analysis of the themes that emerged from interviews with stroke survivors and caregivers, which highlights the impact of Emotions2Us on wellbeing practices, and (3) an in-depth reflection on the challenges, benefits, and opportunities involved in designing technologies to facilitate social sensemaking post-stroke. This study addresses gaps in the literature by integrating the design of technologies aimed at promoting the emotional wellbeing of both stroke survivors and their caregivers by considering one's wellbeing as a social and interdependent construction. These contributions are crucial for both designers of wellbeing technologies and researchers in stroke rehabilitation, as they provide insights and a foundation for developing technologies that enhance wellbeing by promoting social sensemaking.

2 Related Work

In this section, we present previous research focused on (1) Wellbeing for Stroke Survivors, (2) Technologies for Emotional Awareness, and (3) Social Sensemaking Technologies.

2.1 Wellbeing for Stroke Survivors and Caregivers

The impact of a stroke can vary significantly based on the size and location of the brain injury, often leading stroke survivors to become reliant on others[50, 52]. They require support in their daily activities [78] and throughout the rehabilitation process [90]. Families play a pivotal role in adapting to the lifestyle changes brought about by a stroke, especially in terms of providing care,

facilitating socialisation, aiding in recovery, and ensuring the wellbeing of the survivors. Usually, it is a family member who takes on the role of primary caregiver. Caregivers assume a crucial and intricate role in the lives of stroke survivors by offering vital, long-term support encompassing physical, mental, and emotional aspects [8, 107]. They assist survivors in their rehabilitation efforts in their multidisciplinary treatments, including physical rehabilitation, speech therapy, occupational therapy and cognitive therapy [68].

After a stroke, both survivors and caregivers experience a significant impact on their wellbeing and quality of life [33, 52]. Caregivers undergo significant changes in their lifestyle and emotional wellbeing, leading to shifts in routines and activities[8, 102]. Also, most stroke survivors typically reside at home with their family members, resulting in notable adjustments in family dynamics, including shifts in roles, routines, and emotional responses[35]. These transitions bring about psychological challenges for survivors, their caregivers, and families[38, 102, 107]. It is crucial for the emotional wellbeing of all involved to be properly addressed, enabling them to prioritise recovery and effectively adapt to the changes in their lives [69, 75]. Thus, post-stroke emotional support is key in promoting the emotional wellbeing of dyads [16, 79, 87, 102, 107].

Studies exploring mental health, emotional wellbeing and social wellbeing are conducted across various fields, including HCI, and focus on different contexts and groups. These groups include non-disabled adults [41, 71, 83], caregivers of older adults [53], older adults [3, 28, 36, 47, 48, 70, 92, 96, 126], autist adults [128], children [5, 110, 116], adolescents with chronic illness [56], people with dementia [46], work teams [43], couples [73], and university students [94, 105]. However, stroke survivors and their care network support are largely unexplored when designing for emotional wellbeing.

Prior research has started considering both stakeholders when designing novel technologies [2, 4, 16, 39, 79, 87, 102]. An example is the work of Aljaroodi et al. [4], who created an empathetic avatar using a mobile application. The application enabled health professionals to gain insights from the rehabilitation process while aiming to increase the motivation of stroke survivors throughout the process. The application used empathetic patient-centred scenarios, characters, and animations of rehabilitation exercises in familiar environments. These strategies promoted engagement, increasing survivors' psychological and physical capabilities. Aldehaim et al. [2] systematically reviewed existing technologies to help caregivers of stroke survivors in various care-related areas, such as depression, problem-solving, health status, social support, preparedness, and healthcare utilisation. Findings show that early interventions improve outcomes in these areas of care. Moreover, results highlight the important role of technology in such interventions to help caregivers. Furthermore, findings show that early interventions improve outcomes in various areas. Another systematic review by Freund et al. [39] showed that using information and communications technology interventions with survivors and their caregivers can benefit the dyads. The technologies used in the various studies included web-based support programs and mobile applications. Results show that dyads often have high adherence and acceptance of novel technologies, which result in positive effects in terms of stroke-specific outcomes, physical outcomes, behavioural outcomes and health service use. In this way, some of the work on technology already considers the dyad as a target. However, most work is based on individualistic approaches, considering only the survivor or the caregiver. Even fewer studies focus on technology and the wellbeing of the dyad.

2.2 Technologies for Emotional Awareness

Emotional awareness has shown promise to change people's perspective and behaviour [10, 15, 123], reduce the sense of caregiving burden [46] and act as a self-regulation tool to alleviate worry and enhance healthy coping mechanisms[12, 32]. Ambient Orb is an ambient device that effectively displays emotional data through changes of colour [97]. This device has been used to promote the

presence and awareness of absent school children [49] and establish connections with their home environment [119]. Another example is the study by Theofanopoulou et al. [110], which used an interactive object to help regulate the children's emotions within an emotional wellbeing context.

Other studies have explored the effectiveness of tangible objects and interfaces in self-reporting emotional experiences, communicating with others, and enhancing personal emotional awareness [5, 41, 43, 47, 48, 75, 113, 123]. An example is a study by Fuentes et al. [41] that uses a tangible interface called the *EmoBall*, which featured a physical ball with a small LED matrix display representing positive and negative emotions with "faces". Similarly, Alsmeyer et al. [5] explored the use of a ball of lights known as the *Subtle Stone*, which captured the emotional states of students in contexts such as the classroom, allowing the teacher to perceive the students' emotional state. Both studies concluded that these tangible interfaces effectively help communicate emotional states and enhance users' self-awareness of their emotions and feelings. We build on this body of work by investigating how an interactive ambient display can be used to collect, express, and support sensemaking of the emotional wellbeing of stroke survivors and their caregivers.

2.3 Social Sensemaking Technologies

While technology has shown potential to aid in stroke recovery and wellbeing [10, 42, 103, 104, 118], most research fails to consider the dyad of stroke survivors and caregivers, either targeting one or the other individually. Still, works with different user groups, such as chronically ill adolescents and their caregivers[56], have highlighted the importance of analysing the experience of dyads when designing technologies that promote care and emotional wellbeing.

Social sensemaking technologies have previously focused on dyads of closely or intimately related people [11, 17, 44, 60, 81, 115, 117, 127]. You et al. [127] explored the emotional wellbeing awareness of workers facing extended work hours. The proposed system addressed bottlenecks in workers' awareness, information interpretation and subsequent behaviour change. In addition, the authors examined the impact of sharing these emotional states with someone close to workers. Findings demonstrated that social sensemaking technology increased workers' self-awareness and intention to modify behaviours while fostering awareness between peers. In addition, results suggested that sharing personal data with intimate partners can benefit health and wellbeing. Mueller et al. [81] presented the design and implementation of a "hugging" interface, which consisted of a wearable device that could simulate the sensation of a hug. The device used air-inflated cushions to mimic the pressure of a hug. The system was designed to convey the emotional warmth of a real hug. The main focus was creating a system that allowed users to send and receive hugs, an inherently physical and emotional gesture, despite being separated by geographical barriers. Visser et al. [117] explored the design of interactive systems to enhance social connectedness, particularly for elderly people living independently. They designed the SnowGlobe, an ambient device to foster a sense of social presence and connection between family members. The research emphasised the importance of emotional design and familiarity in creating ambient devices for social connectedness and demonstrated how ambient display systems can effectively support social connectedness.

Social sensemaking technologies usually leverage the concept of Positive Computing, i.e., the potential of interactive technologies to support people's wellbeing, emphasising positive emotions, motivation, and self-awareness. As a result, such an approach has been used to promote individuals' and groups' emotional and social wellbeing [10, 19–21, 40, 94, 100, 104, 105, 116]. Snyder et al. [105] studied how awareness and exposure to a person's level of arousal influence people in personal and social terms. The authors created MoodLight, an interactive ambient lighting system that maps the level of arousal to a colour to promote self-awareness. The arousal level was measured through a wearable electrodermal activity sensor and shown at a light ambient display (desk lamp). Findings show that the display influenced people's and others' mood perceptions. Frey et al.

[40] used breathing patterns to investigate how one perceives emotions. They created a necklace pendant - *Breeze* - to display the biofeedback, which illustrated the breathing measurements in real-time, modulating audio and haptic output and light brightness (light intensity) to adapt to visual feedback. The device can promote individual internal awareness and mediation of social interaction with other people, increasing connectedness and empathy levels. Rodgers et al. [94] investigated the assessment of an individual's wellbeing by leveraging collaborative technologies to express, interpret, discuss, and foster wellbeing. They created a technological probe called *MoodCloud*, consisting of a mobile application in which students conveyed their emotional states through colours, shown and displayed in their friend's app. Moreover, students' emotional state was also displayed in a cloud-shaped device at their friends' homes. *MoodCloud* promoted an open-ended interpretation. Due to the ambiguity of the emotion-based colours, peers resorted to channels that supported verbal and bodily communication within the application to enable mutual awareness, reciprocity and commitment to the relationships. The authors introduce the concept of "wellbeing-as-interaction" to highlight that wellbeing is at least to some extent socially constructed and is the result of interactions with others.

Overall, this research underscores the crucial role of self-awareness regarding emotional wellbeing and how understanding a partner's emotional state can shape the emotions and behaviours of both individuals. This dynamic fosters an enhanced relationship and deepens the connection within the dyad. These findings reinforce and inform the foundation of our work, which focuses on stroke survivors and their caregivers.

3 Emotions2Us

The Emotions2Us prototype was designed to promote and raise emotional wellbeing awareness by sharing the emotional state between the caregiver and survivor. By designing this prototype, we aim to bridge a gap in post-stroke life: the survivor's and caregiver's lack of emotional support [102]. Emotions2Us was the name chosen for the prototype, combining the words emotions with "2Us", which refers to the two main stakeholders, the survivor and the caregiver. Moreover, it reflects the prototype's main goal of emotional sharing between the dyad. Emotions2Us is a social sensemaking technology that consists of an RGB lamp that reflects the combined emotional states of the stroke survivor and caregiver.

3.1 Emotions2Us Design

Emotions2Us emerged from the needs that stroke survivors and caregivers reported, specifically concerning the negative emotional impact of a stroke and the importance of including the caregivers in the rehabilitation process [16, 102]. We designed Emotions2Us to be collaboratively used and shared by the dyad. The design of the prototype drew inspiration from prior work on emotional expression, awareness, and social sensemaking technologies [5, 40, 41, 94, 97, 105, 127]. It was further informed by feedback from the various authors of this paper, who have backgrounds in HCI, Accessibility, and Psychology. These disciplines worked together throughout the design process to ensure the prototype addressed both technological and psychological aspects of emotional wellbeing. The development followed select principles of embodied sensemaking technologies [19, 59], adapted to a context where users did not necessarily interact with the system simultaneously or face-to-face. Instead, Emotions2Us was designed to promote asynchronous awareness of others' wellbeing states, support interpersonal communication [44], foster collaborative decision-making, and encourage mutual care. While Hummels and van Dijk's [59] principles are rooted in face-to-face, ongoing sensorimotor coupling, and our system leveraged key aspects, such as promoting awareness and reflection on emotional states through shared ambient displays, which facilitated indirect but meaningful face-to-face interactions. Furthermore, we created Emotions2Us as a tangible ambient

device that incorporates concepts from tangible technologies to enhance experience engagement [84, 124] and from home technological devices to seamlessly integrate into the home environment [24, 66, 75, 91], encouraging spontaneous and collaborative interaction within the dyad. Thus, we use a single interactive object to input data and show the emotional state of both stakeholders through a colour code. The prototype comprises an RGB lamp (Xiaomi Bedside Lamp 2), a microcontroller (Raspberry Pi 3), a seven-button keyboard, and a 3D-printed case. We chose a lamp as a familiar, appealing, and calm technology [22, 122] that minimises disruption in people's homes.

Users can easily place the device in the most convenient place in their home (Figure 2).

Fig. 2. Emotions2Us at the participant's home.

Emotions2Us features a keyboard with seven push buttons to select one's emotional state (Figure 3). The seven-button keyboard has two squared buttons representing each stakeholder and five circled buttons representing a five-point scale of emotional valence [14]. The seven-button keyboard and microcontroller are encapsulated in a cylindrical 3D-printed case that serves as a base and matches the minimalist design of the lamp (Figure 1).

We opted to represent valence as this is one of the most important concepts for expressing an individual's emotional experience [23, 106]. Emotional valence refers to the subjective positive or negative rate of an emotional experience, like a stimulus expressed on a continuum from pleasant to unpleasant. It is the degree to which a person perceives their emotions [14, 67, 98, 121]. This one-dimensional view of emotion enables a brief and minimally disruptive expression of emotional states [26, 101, 106]. Moreover, we drew inspiration from the five-point valence SAM (Self-Assessment Manikin) scale [14] and added non-verbal emotional representations to the rating scale to improve accessibility [14, 18, 80]. The valence SAM scale is a non-verbal pictorial assessment technique used to measure emotional valence (positive vs. negative) consisting of figures/manikins [14]. The colour choice was based on the Traffic Light System (TLS), which has been successfully used in various domains related to emotional expression [9, 64, 76, 93, 111]. By combining non-verbal representations with colour-coded states, we aimed to improve understandability and facilitate emotional expression [14, 18]. Overall, the SAM scale is often used in various psychological studies [18, 58, 63, 108].

In terms of output, the emotional state is represented by the light colour. To foster a sense of comfort and genuine expression in emotional sharing, we introduced some ambiguity [45, 112] in

the feedback by combining the colours of both emotional states. Thus, rather than representing the emotional state of a single stakeholder, Emotions2Us represents the joint emotional state of the dyad. This design option aims to foster reflection and a sense of togetherness.

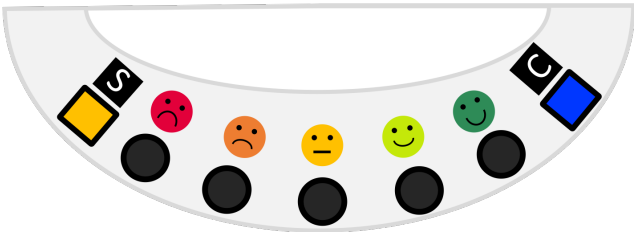

Fig. 3. Interactive keyboard of Emotions2Us.

Finally, we used a *Raspberry Pi 3* to collect and store users' input while controlling the lamp output. The *Raspberry Pi 3* also served as a hotspot for the Xiaomi Lamp, thus working as a stand-alone device without dependence on the house WiFi. The prototype was implemented using *Python* (3.10.10).

3.2 Emotions2Us Interaction Design

Emotions2Us behaves the same way for both stakeholders interacting with it. Therefore, we used seven tangible buttons to promote direct interaction with Emotions2US. We chose to use only seven buttons to select the emotional state and user who is interacting to minimise the complexity of interaction with the system and thus facilitate emotional expression on the part of the dyad. The yellow squared button with the letter 'S' is intended for the survivor, while the blue button with the letter 'C' is intended for the caregivers. Whenever users want to update and share their emotional state, they press the corresponding button and select one of the black buttons on the scale with corresponding "emotional faces" at the top. This scale is read from left to right, where the red face represents a negative emotional valence, and the green represents a positive emotional valence. The yellow face represents a neutral emotion. Emotions2Us reflects, on the lamp, the combined emotional state of the dyads through a colour only when both users have selected their rating at least once that day. Otherwise, the light remains white. The combined colour hue is calculated by averaging the participant's individual ratings and selecting the corresponding hue through a linear interpolation in the previously described scale (red - orange - yellow - light green - dark green, Figure 3). For example, if the survivor indicates a dark green emotional state and the caregiver indicates a yellow emotional state, then the colour of the Emotions2Us light will be light green. Users cannot see others' emotional states without inputting their own, creating an equal and interdependent interactive context.

The light's colour remains white until survivors and caregivers enter their emotional state. If the dyad has not entered its emotional state by 5 p.m., Emotions2Us progressively calls for users' attention by smoothly blinking. This reminds participants to engage with the prototype. This behaviour occurs whether none or just one of the stakeholders has entered their emotional state. At 5 a.m., the emotional states are reset, and Emotions2Us turns white.

4 Methodology

This study investigates the potential of the survivor's and caregiver's awareness of their emotional wellbeing through their interaction with Emotions2Us, a social sensemaking technology. The study was approved by the Instituto Superior Técnico Ethical Committee.

4.1 Positionality Statement

As researchers committed to understanding and supporting the emotional and social wellbeing of stroke survivors and their caregivers, we deeply value our study communities and recognise the importance of deeply integrating into them through active engagement and participation. By attending community events and support groups, we build trust and gain deep insights into the daily experiences and challenges stroke survivors and caregivers face. This integration allows us to tailor our research and interventions to these individuals' specific needs and contexts, ensuring that our work is both relevant and impactful.

Our multidisciplinary team, who have backgrounds in Human-Computer Interaction (HCI), Accessibility, and Psychology, brings a unique combination of expertise to this research. Our research follows a process of investigation, action, and intervention. We begin by investigating stroke survivors' and caregivers' specific emotional and social needs to understand the community's needs and preferences [16, 102], drawing on our knowledge of HCI to design accessible, user-centered technologies and leveraging psychological insights to address emotional wellbeing. Furthermore, we contacted stroke survivors and caregivers directly and became involved in community events. This deep involvement shaped our design and research practices, underscoring the importance of rehabilitation and wellbeing after a stroke.

In this way, we learned how to explore dyad emotional wellbeing through a social model, considering that accessibility is built on the interaction between the environment, people, and relationships. Our positionality as researchers is guided by a commitment to making a positive, tangible difference in the lives of stroke survivors and their caregivers and to advancing the field of emotional and social wellbeing support through community-informed and action-oriented research.

4.2 Participants

We recruited eight pairs whose survivors had suffered a stroke within the last 12 years. For this experiment, we recruited participants through direct contact and a local support organisation for stroke survivors. As inclusion criteria, participants had to be a dyad of stroke survivors and caregivers living in the same house. Exclusion criteria included people with colour blindness or a high degree of depression according to the GDS-30 scale [125]. The study researchers and a trained psychologist on the research team carried out this assessment. If any of the participants were severely depressed (high), they would be referred by the team's psychologist to a professional. None of the participants presented a high degree of depression. All the participants were Portuguese, aged between 26 and 82 (M=54.8, SD=15.9). The relationship between the survivors and caregivers was that of a couple or parent-son/daughter. Table 1 shows the participants' demographic data in more detail.

4.3 Procedure

The study was carried out in three phases. The first phase consisted of individual questionnaires (colour blindness test and 30-Geriatric Depression Scale (30-GDS) [125]) to determine the participants of the study, considering the inclusion and exclusion parameters. Participants with colour blindness or a high degree of depression (a score of 20 or above typically indicates a high degree of depression on the 30-GDS) could not participate in this study.

In the second stage, we conducted an interview with the dyad either in-person or remotely via Zoom (at the participant's preference). This first interview was used to build rapport and characterise the dyad regarding demographics, type of stroke, and onset age. We also explored what kind of experience or contact participants had with psychological and emotional support services and their overall emotional wellbeing. Finally, we installed the Emotions2Us prototype in

the participant's homes and briefly explained how to use the device. The prototype remained in the participants' houses for a month.

In the third phase, we removed the device from the participants' houses and conducted two post-study interviews with the dyad, either in-person or remotely, according to their preference. The first interview was conducted on the day we removed Emotions2Us from the dyads' house, where we explored their individual and joint experience with Emotions2Us, the enablers and barriers of using the prototype, whether and how the device changed routines, and their perspectives on using the prototype to make sense of emotional wellbeing data. Finally, we conducted the second interview one week after participants stopped using Emotions2Us to gain further insights into the dependency and impact of the device on the dyads' lives. We leverage the "removal as a method" approach [55] to reveal otherwise hidden knowledge. Such an approach has shown to be particularly useful in documenting the impact of everyday and self-tracking technologies. Thus, after a month of daily use, we removed Emotions2Us from dyads' homes to better understand the technological attachment that participants created with the device [6]. The interview guides with all questions from each phase are available as supplementary materials.

All participants signed a consent form at the beginning of the study. In the end, each dyad was compensated for their participation with a €50 Amazon gift card.

4.4 Analysis

All the interviews conducted in this study were audio-recorded and transcribed. We followed an iterative coding process to analyse the data and its thematic analysis [57]. Using an inductive approach, two researchers with the same background independently created a codebook from two first interviews. The codebook was then refined and merged. The codes covered communication, caregiver inclusion, emotional states, sharing, emotional support, and the interaction with Emotions2Us, as well as the impact of the stroke. After reaching a consensus on the first interviews codebook, the two researchers then coded a subset of 14 selected excerpts from the first interviews, to consider examples from all dyads' interviews, followed by two iterations of refinement and comparison. Finally, Cohen's kappa was calculated to assess inter-rater reliability. The average kappa score for all the codes was 0.95 (SD=0.09, range 0.76 to 1.00). The two researchers then coded a subset of the remaining first interviews independently. At this stage, if one of the researchers felt the need to use a new code, they would discuss it with each other and add the code to the codebook in case of agreement. The same process was carried out for both post-study interviews, and the codes from the first interviews were added to the codebook. After reaching a consensus on the codebook for the post-study interviews, a subset of 11 excerpts were selected and coded. Cohen's kappa was also calculated with an average score of 0.85 (SD=0.18, range 0.56 to 1.00). Finally, both researchers independently coded the subset of the remaining post-study interviews.

5 Findings

In this section, we present quantitative results emerging from the dyads' usage of Emotions2Us, and the findings from the qualitative analysis of the interviews conducted throughout the study. The interviews conducted with the dyads (D) gave us a broad view of the importance of emotional wellbeing for the survivor (S) and caregiver (C), how they express and reflect on emotions, how they communicate with each other, and the importance of emotional care. Thus, this section highlights the most relevant findings, including current emotional wellbeing support (subsection 5.2), influences of Emotions2Us on the individual (subsection 5.3), influences of Emotions2Us on the dyad and beyond (subsection 5.4), and how the prototype facilitated the expression of emotional states (subsection 5.5).

DYAD ID	S/C Age	S/C Gender	Stroke Onset (years)	Type of Stroke	Relationship
D1	82 / 76	M / F	5	Ischemic	Couple
D2	47 / 50	F / M	12	Ischemic	Couple
D3	43 / 43	M / F	2	Ischemic	Couple
D4	59 / 69	F / M	4	Hemorrhagic	Couple
D5	58 / 76	M / F	8	Ischemic	Son and Mother
D6	28 / 53	F / F	8	Hemorrhagic	Daughter and Mother
D7	55 / 26	F / F	1	Ischemic	Mother and Daughter
D8	54 / 58	M / F	1	Ischemic	Couple

Table 1. Demographic information about participants. S - Survivor, C - Caregiver, F - Female, M - Male.

5.1 Day-to-day Interactions with the Emotions2Us

Figure 4 shows the daily emotional states of the dyads throughout the study. Overall, Emotions2Us promoted the sharing of emotional states between survivor and caregiver. Interacting with Emotions2Us demonstrated potential to become a meaningful activity of the dyads' day-to-day lives. During the experimental month (31 days), the number of days the dyads interacted with Emotions2Us varied between 25 and 31 days, with 37.5% of the dyads interacting during the 31 days. The average number of interaction days was 28.75 (SD= 2.32). In addition to the commitment to daily interaction with Emotions2Us, the average number of interactions per participant per day was 1.94 (SD=1.32), which shows engagement on the part of survivors and caregivers.

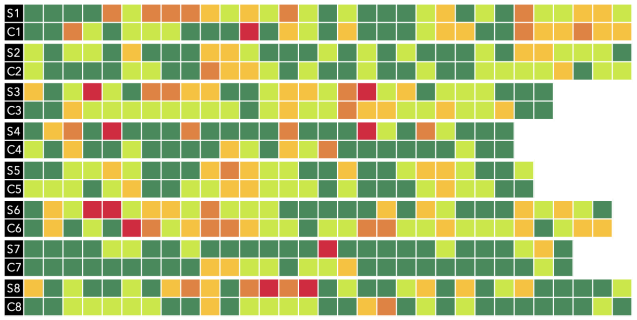

Fig. 4. Emotional state of stroke survivors (S) and caregivers' (C) daily interactions. Each colour corresponds to the emotional scale present in Emotions2Us, going from a positive emotional state in dark green to a negative emotional state in red.

5.2 Current Emotional Wellbeing Support

Participants reported they had limited access to or did not want emotional support from health professionals after a stroke. Few received emotional support from health professionals, like survivors (S3, S6), who received psychological support but just during hospitalisation or rehabilitation (C3 mentioned *"S3 was receiving psychological support at Alcoitão [rehabilitation centre]. At the moment, it has stopped because he has been discharged [...]"*). Others (S2, S4) obtained such are at their local health centres (S2 highlighted, *"[...] I was lucky to speak to my general practitioner about my desire to see someone specialised [...], and she made the request and [...] I was lucky to have a trainee psychologist*

at the health centre [...]".). However, other participants reported they had never been advised to receive emotional support (D5), and most of them mentioned the lack of psychological support for caregivers (C1, C2, C4, C5, C8). C2 described his case, *"To answer whether we had psychological help from a psychologist, I did not, I should have. I did not. Maybe I am suffering a bit from the consequences of not having had it at the time. I was not advised either. I was not recommended [to seek help]. I was in the public health system, [...] I did not even have a consultation."*.

C1 went even further and said: *"We have never had any psychological support. Not after the stroke, not even now, with the various episodes of transient ischaemic attack. I do not think S1 has ever felt comfortable going to a psychologist either."*, showing S1's discomfort with going to a psychologist to discuss emotional problems. This example underlines the stigma that some people feel uncomfortable attending a psychologist to receive psychological support from health professionals.

Considering that emotional support is essential for the survivors' recovery and the wellbeing of the dyad [16, 79, 102], some participants were forced to look for alternatives like coping methods and strategies to promote their emotional wellbeing. These coping methods were as varied as physical activity, being with friends or resorting to alternative medicines. D6 explained that despite being given the option to receive psychological support at the hospital, they felt that hospital services did not match their needs, so as regular Reiki practitioners, they prefer practising Reiki to take care of their emotional wellbeing, an alternative medicine that works with essential energy of a person, as C6 put it *"We were given psychological support. I did not want it, S6 did not want it either. S6 went twice but said she did not want to go [again] [...]"*. They added *"She [reiki practitioner] is a therapist for us [...] an emotional therapist. [...] there is nothing we do not talk about [...] in that sense, she is an emotional therapist, and it has been very good for both of us [...] from the beginning."*. This was also the case for C2 and C3. Physical exercise was primarily characterised as a source of enjoyment and tranquillity. C2 mentioned he practised martial arts, while survivors S1, S3 and S7 pointed out that walking was one of the things that helped them relax. It provided mental clarity and allowed them to engage in physical exercise. Furthermore, our participants mentioned spiritual activities, such as yoga, meditation, and praying (C2, S4, C7, S7), as a way of *"increasing their energy"*. Another important activity was socialising, being with friends or being part of a community through a *WhatsApp* (C1, C6, S6) or *Facebook* (C1, S4, C5, S5) group, or pursuing hobbies such as reading the newspaper (S1) and gardening (S4). To summarise, C2 highlighted *"For my wellbeing, I think it is all a question of the person getting into a mindset and doing things that they enjoy and that bring them added value."*.

Thus, with the lack of emotional support from health professionals and the discomfort of going to a psychologist, the dyads must explore alternative mechanisms to promote their emotional wellbeing and mutual emotional care support.

5.3 Influences of Emotions2Us on the Individual

Participants in the study highlighted the transformative impact of Emotions2Us on their individual emotional wellbeing, namely increased awareness of themselves and others, increased self-reflection and empathy.

5.3.1 ***Increased Awareness of Self and Others.*** Emotions2Us enhanced emotional self-awareness and interpersonal understanding. S7 emphasised how using the prototype significantly improved their emotional wellbeing by stating *"The light [...] came at a time when I felt very bad, emotionally fragile and psychologically affected, and the light helped me, above all, to understand others, to understand the other side and to be able to understand how others were, to see the other side and also to see how I felt. It helped me a lot, and now I feel much better after having the light here [...] it helped me a lot psychologically [...]."*. C3 noted that Emotions2Us' main benefit was understanding each

other's emotions. Still, she highlighted how it improved her awareness of mood fluctuations and encouraged a reflective process, fostering the ability to analyse and even influence her emotional state. She stated that *"[...] I am aware, or paying attention to my mood, thinking about why I was like that, and knowing the reason."*.

5.3.2 ***Increased Self-Reflection and Empathy.*** While fostering an enhanced sense of awareness, Emotions2Us also prompted introspection among participants. Similarly to C3, C1 expressed how it encouraged reflection on daily actions and emotions, allowing for more open expression about their emotions. She stated that *"It made me reflect a lot on the actions of the day and my own emotional state. It was an enriching experience [...] because it made us see the other side of ourselves...of expressing ourselves, saying how we are, and worrying about others."*. C5 and S1 echoed this sentiment, emphasising how Emotions2Us prompted them to contemplate their feelings and how they manifested in their home environment. Also, D7 described how it facilitated a deeper understanding of emotions. C7 said, *"Sometimes I would look at it [Emotions2Us] and think, 'OK, that makes sense, is it orange or is it red because we argued, because we yelled at each other'. For example, it was green, and I would think, 'Oh, well, she went to physiotherapy today, it went well, there was nothing, and I do not remember there being any arguments'. Thus, it was a bit of thinking along those lines. The light [...] was to promote reflection on all the actions that had taken place throughout the day. I thought about everything that had happened during the day and could understand and interpret why the light was that colour, and I made a bit of a deduction."*. In these quotes, participants paid attention to their emotional states and cross-referenced with their observations of daily events and others' conditions, showing the role of Emotions2Us in promoting reflection. C7 continued by mentioning how reflecting on the day's events could lead to changes in individual behaviours: *"[...] it made me think about what I could change that day so that I could be better and enjoy the day analysed, not ruin it."*

Summary *These findings highlight that Emotions2Us profoundly influenced individual users by* ***enhancing emotional self-awareness*** *and* ***interpersonal understanding*** *(5.3.1),* ***promoting introspection*** *and* ***encouraging reflection on daily actions/activities and emotions*** *(5.3.2). Through this process, users could express their emotions openly, reflect on their experiences, and adjust daily routines. Increasing emotional clarity and reflection, strengthening mutual support and contributing to the overall emotional wellbeing of stroke survivors and their caregivers.*

5.4 Influences on the Dyad and Beyond

Emotions2Us exerted several influences on the dyads of stroke survivors and their caregivers, extending its impact beyond them. Each subsection uncovers a specific aspect of this experience. From communication to mutual care and shared emotional labour, Emotions2Us acted as a catalyst for change. We examine how it fostered understanding and social sensemaking while playing a role in deepening relationships, prompting changes in behaviours, and coordinating change. These effects were reported to lead to lasting changes, influencing beyond the dyad to other household family members.

5.4.1 ***Improved Communication.*** Emotions2Us is an interactive device designed to promote mutual awareness of the emotional states of the stroke survivor and caregiver. This awareness promoted reflection about one's emotional state and that of others, which ultimately enhanced communication, illustrated by C4's comment *"We [...] were able to understand how each other felt. It is interesting when we can see [the emotional state] of both of us at the same time because it makes us think more as a group, as a couple [...], because it makes us reflect on both of us [...] and that is what also promotes communication."*. Participants acknowledged its potential to unblock and trigger

communication (D7, S2, S1), adding that Emotions2Us made them feel supported and comfortable talking to each other about their emotions. S1 said that *"[Emotions2Us] led us to talk more about how we felt. I think she [C1] would make a good psychologist because she has supported [me in] everything."*.

5.4.2 ***Mutual Care and Shared Emotional Labour***. Participants noted that other than supporting mutual awareness, Emotions2Us also encouraged mutual care and looked for strategies to improve each other's emotional state, an important factor in the stroke survivor and caregiver relationship. C5 explained mutual care as *"there ends up being this sharing and concern for each other, and maybe sometimes we could ignore and not talk about certain issues, but now we end up [...] realising how each one is, and wanting to know more and [...] why"*. Also, D4 described how they shared a common goal of achieving a green light when combining their emotional states on Emotions2Us. S4 said, *"Yes, so that the light would always be greener because that was our goal. We are very calm, positive people. We try to be positive, but sometimes we get down. So we ended up trying to make each other's day better, [...] it ended up stimulating other activities and other things that we might not have done otherwise."*. In the absence of psychological support from health professionals, Emotions2Us was reported to facilitate the promotion of mutual support between the dyads and help the caregivers with their emotional labour [7, 54]. S4 added *"C4 never had [psychological support from health professionals]. He always gave me all the support he could, so it was a way for us to help each other. I think it was a good way of integrating this psychological help, of giving each other emotional support."*. C4 echoed this feeling.

5.4.3 ***Social Sensemaking***. Beyond improving their communication, dyads were motivated to jointly understand what led to a certain emotional state rather than how they felt. On the one hand, several participants (D1, D3, D4, D5, D6, and D8) described their experiences of being encouraged to social sensemaking and participation, as both survivors and caregivers frequently asked each other if they had already reported their emotional state on Emotions2Us. S8 said *"C8 was always saying: 'So have you been there to see?', 'Have you been there to press the button?'"*. Moreover, participants explained the motivation behind their social sensemaking, which was especially triggered by wanting to understand the reasons for that emotional state. C4 said, *"I could see how she was [...] [by seeing the] colour that was in the light, and [...] we ended up talking to understand why she was like that."*. The same happened with D7 and D5, who described that by promoting social sensemaking, Emotions2Us helped them prevent arguments between the dyads for lack of understanding. C5 shared that *"We ended up communicating with each other and we ended up talking to each other to understand what was going on. [...] the light being here at home was a great help because we already had communication problems before, it was always a problem; we would get upset with each other, argue, and sometimes we did not even know why.[...] it changed in the sense that we wanted to know why [the other person was in a certain emotional state]"*.

Aphasia is a sequela that affects communication and can impact speech, writing, and understanding of spoken or written language due to damage in specific brain regions [29]. In the particular case of stroke survivors with aphasia, Emotions2Us proved especially useful to support the dyad, communicating emotions and helping the caregiver understand the survivor's emotional states. C3 explained, *"It was easier to visualise than it is sometimes to interact directly because of the communication difficulties [S3 has aphasia]. You cannot tell if the person is really sad. For example, sometimes I thought S3 was sad because he was standing still, and I would ask him, and he would... [say] 'No!'. A lot of the time, I kept asking him. With Godofredo [Emotions2Us], I did not need to do it so often [...] I could see. [...] to understand a little about how S3 was feeling [...] without always bothering him with questions."*.

5.4.4 ***Deepen Relationships.*** Some participants pointed out that Emotions2Us enable them to change how they see each other, communicate, and practice care. C6 and S6, for instance, with Emotions2Us, showed themselves to be more alert and concerned about each other's emotional state to be more supportive of each other, strengthening their mother-daughter relationship. S7 and C7, for example, reported that before the study, they often clashed, and the relationship between them and the rest of the family was distant. As C7 said, *"It brought us a slightly different way of thinking and acting because I started worrying more about what my mother was feeling [...] about what was happening [...] 'OK, I am like this, or my mother is like this for this reason or that' and then trying to figure out how we could change and how we could act by talking to each other so that things would improve and I think this has improved a lot."*. C7 also recalled *"My mother didn't communicate with us as much and we didn't [talk] to her either, and the light [Emotions2Us] has unblocked this thing of worrying about others and ourselves as well. It was [...] about unblocking the psychological part [...] being able to talk to each other. For example, just the other day, my mother was screaming, and I said, 'Mum, there is no need to scream'. [...] Now I talk to my mother a lot more, and we try to externalise what we feel, and [...] talk more about what we feel. This is something that the light [Emotions2Us] has changed a lot in us and has helped us a lot."*. D7 thus experienced a positive change in their lives that affected both of them, deepening and strengthening their relationship. Participants reported being more sensitive and experiencing the feelings, thoughts and experiences of others.

C7 comments were reciprocated by S7, who added that Emotions2Us allowed her to *"understand the other side more clearly and establish more communication, talk to each other more, allow us to talk better and understand each other better."*. In this case, by making covert emotional states visible, Emotions2Us lowered communication barriers, serving as a trigger to create new communication channels to promote mutual understanding and empathy towards others.

5.4.5 ***Change in Individual Behaviours.*** Emotions2Us brought about several changes in the participants' lives due to their enhanced awareness and social sensemaking. C1 mentioned, *"I reflect a lot on the actions of the day and my emotional state, being able to reflect on how I felt and how S1 felt. [...] Thinking about what made us like this and what I could do to improve it. [...] It makes you think beyond what you feel. It makes you think about your actions."*. Among other things, self and joint reflection resulted in small changes in each person's behaviours, as mentioned by C1, S1, C3, S4, C5, C6, S6, C7, S7 and C8. C5 mentioned that *"it changed in the sense that we wanted to know why [the other person was in a certain emotional state]. It changed [...] our lives in the sense that we were able to express ourselves better [the way we felt]"*. C1 shared that Emotions2Us made her *"[...] reflect a lot on the actions of the day and [...] [her] own emotional state [...] in a way it gave [...] a push to think about it more and act differently in certain situations."*. Furthermore, S1, C3 and S7 also mention that they continue to think about their feelings and have this new practice of reflecting on their emotional state.

5.4.6 ***Lasting Changes and New Dynamics.*** After a month of using Emotions2Us, the survivor and the caregiver had acquired new dynamics. Participants reported that after the experiment, they maintained improved communication habits acquired through interaction with the Emotions2US (S4, C5, C1, S1, C3, C7). S1 explained *"I mean, we do not have the routine of going there to inputting how we feel on the light [Emotions2Us], but we talk a bit more about how we feel, just the other day, you [C1] were asking me how I felt."* and S4 mentioned, *"We still talk like before [with Emotions2Us] and talk to each other, but we miss the little light!"*.

After the experience, some participants began reflecting on their emotional state more often (C3, S7 and C8). C3 said, *"I am still doing [the exercise of thinking about my emotional state]. I have started doing that exercise of analysing why I feel this way or why I am like this."*. S7 also explained her tactic of thinking about how she would manifest her emotions through the colour-coded light,

"I use it a lot [...] that idea [...] that the light is in my head and it seems that [...] I think [...] today I am green, [...] in a way I have also continued to do this reflection, at least on my part.". Emotions2Us changed the routine of the caregivers and survivors and promoted the establishment of new habits of thought and reflection on emotional wellbeing.

5.4.7 ***Influence on Other Family Members.*** The interaction of another family member and changes in family dynamics was something that some dyads mentioned, such as D3, D5 and D6. C3 said that the couple's young son was sometimes curious about going and touching Emotions2Us. S5 mentioned that he had started to talk to C5 more and that even the father, who lives with D5, had also started to become more aware of the dyad's emotional wellbeing and to communicate more as if it were a third element in the experience. S5 explained,*"The light changed our daily life a little because we came here to interact, understand each other's emotional state better, and reflect and communicate more. Above all, I think it was also talking to each other more about why we were like this. Even my father ended up talking more and asking questions. He joined into the experience because even though he did not say how he felt, he would worry when he realised that we both were not doing well or if we were both doing well. It was funny that sometimes he said, 'You have not interacted with it [Emotions2Us][...] yet today', and it was interesting how he ended up entering into the interaction of the light and the experience."*. S6 mentioned, *"Even Dad used to mess with us"*. Furthermore, C6 added that it felt like *"[...] a family experience. [laughs]"*, due to the father's interventions.

Summary *These findings highlight that Emotions2Us significantly strengthened the emotional and communicative aspects of the relationship between stroke survivors and their caregivers,* ***unblock and trigger communication*** *(5.4.1) and* ***encouraged mutual care*** *and looking for* ***strategies to improve each other's emotional state*** *(5.4.2). Also, the stimulus of Emotions2Us is the motivation behind their* ***social sensemaking****, where the dyad tries to* ***understand the reasons for a certain emotional state*** *(5.4.3), which promotes* ***mutual understanding*** *and empathy towards others,* ***strengthening relationships*** *(5.4.4). Furthermore, Emotions2Us enabled several changes in the participants' lives, resulting in* ***changes in each person's behaviours*** *(5.4.5), which led to dyad acquired* ***new dynamics*** *after the experiment with Emotions2Us, promoting* ***more communication habits*** *and more* ***often emotional wellbeing reflection*** *(5.4.6). These improvements in dyadic interactions also had* ***positive ripple effects on family members*** *(5.4.7).*

5.5 Facilitating Expression of Emotional State

Based on the interview data, we report results on how Emotions2Us lowered barriers for dyads to communicate emotional states to others. Moreover, we convey how such communication went beyond communicating through the device.

5.5.1 ***Influences of Ambiguous and Indirect Expression.*** One of the advantages that Emotions2Us gave survivors and carers was making emotional expression easier. The fact that each person's emotional state was not explicitly stated on Emotions2Us was also an asset for comfort in emotional expression, as S5 mentioned, *"I was also able to convey how I felt, it was easy to interact, the interface was intuitive, I liked the way it was easy to put my emotional state there, [...] my [emotional state] was not [explicitly] visible [...] made me feel more comfortable sharing my emotional state."*.

S4 spoke of her experience with Emotions2Us, *"We got to know our emotional state without me having to ask 'how do you feel?' [...] The light told us how we were, encouraging us to talk or want to know why, so it was a very enriching experience. [...] Understanding how each other feels is very useful, especially for understanding each other's emotional state."*. S4 highlighted how easy it is to know the other person's emotional state without asking.

S1 even drew a parallel between talking to his caregiver and a psychologist. S1 said, *"It is easier for me to reflect on events and how I feel this way than to go and talk to a psychologist."*.

S1 said that Emotions2Us *"started to draw our attention to something that had always been here but that we probably did not pay attention to. [...] It ended up helping me to understand how I felt and to get to know C1 better."*. Also, C6 said that the interaction with Emotions2Us *"[...] is different because we [...] now externalise emotions."*, promoting their emotional expression.

Moreover, C3 described her and S3's case, *"I think what I liked most was [...] having the idea that seeing the two of us together would help us to know more or less how each of us was feeling [...] with the colour it gave. [...] It was easier to visualise than it is sometimes to interact directly because of the communication difficulties [S3 has aphasia]. You cannot tell if the person is really sad. For example, sometimes I thought S3 was sad because he was standing still, and I would ask him, and he would... [say] 'No!'. A lot of the time, I kept asking him. With Godofredo [nickname S3 and C3 given to Emotions2Us], I did not need to do it so often [...] I could see. [...] to understand a little about how S3 was feeling [...] without always overwhelming him with questions."*. Another point that C3 mentioned and which was very relevant was the importance of *"being aware of [my emotional state]... Because in our everyday life, sometimes we do not have a sense of our mood and how it can also impact the other person"*. In this case, C3 referred to our emotional state's impact on others and how much it can influence the emotional state of those around us.

5.5.2 ***Verbal Communication of Emotion.*** After a month of interaction with Emotions2Us, the dyads no longer had the prototype to share their emotional states and promote conversations between them. A week after not using the prototype, we asked them how they shared and reflected on their emotional states and what strategies they have adopted without Emotions2Us. C7 said that one of the strategies she uses now is to *"talk to my friends, I try to talk to them, I talk to my mother, now I talk to my mother a lot more, and we try to externalise what we feel, and we try to talk more about what we feel."*. S7 said, *"[...] continue to talk more now and to externalise what I feel and think, and we can talk more openly, my daughter and me, about what I feel and how I am doing."*. C7 and S7 reinforced that they were now more comfortable communicating and externalising their feelings. Other examples are the cases of dyads D1, D4, and D5, which mention that without Emotions2Us, they try to talk more with each other about how they feel and their emotions. C8 even says she now tries to "think more, for example, not to argue", talk more, and understand S8's emotional state.

5.5.3 ***Missing the Trigger for Communication and Technological Attachment*** . Emotions2Us provided a stimulus for the dyad to communicate due to the awareness it raised of emotional states. Several participants (D1, D5, D6 and D7) recognised that they missed the added communication stimulus, which promoted and facilitated communication between dyads. C5 said that now she tries to *"talk a bit more, [...] but the stimulus it gave us was completely different to the stimulus we get when we talk [now] when we [ask] 'how are you?'"*. She also said that Emotions2Us was a *"great help for us to understand each other a bit better and to talk [...] [also] the type of communication was different compared to now."*.

C5 also mentioned, *"We liked having the light here at home. Now we are sorry it is going away because we liked a lot the interaction we had with it, and it was a great help for us to understand each other a bit. [...] The light was here. It was here for a month, not even that long, and interaction was easy. Now we miss going there every day to say how we feel."*. In addition to dyad D5, all the other dyads (D1, D2, D3, D4, D6, D7 and D8) have shown the technological attachment created with Emotions2Us and the dependence on the stimulus provided by this social sensemaking technology.

5.5.4 ***Increasing Awareness of Health Professionals.*** One aspect participants reported was how the data on emotional states shared between dyads could also be used to help health professionals during the rehabilitation process. S4 said, *"It would be interesting to be able to share this because then they would also be aware of how I was doing."*. C1 commented, *"I think it would be very interesting [sharing data with health professionals] because I remember when rehabilitation was more intensive, and S1 was worse some days than others, and maybe the physiotherapists knowing how he was feeling (in emotional terms) would have helped a lot."*. Furthermore, C3 said it would be interesting to share the emotional state *"at rehabilitation centres like Alcoitão, it could be very important, of course, they always had to have contact with the caregiver, but even at the level of psychologists, for example."*. C7 mentioned, *"If they [therapists] realised how S7 was doing, it would be interesting to adapt the rehabilitation for that day. OK, because sometimes when she [S7] is at her lowest, they can help her more so that she gets better."*. Most participants found it relevant to share information about emotional states with health professionals to promote more personalised care for survivors' rehabilitation therapies.

Summary *These findings highlight that Emotions2Us facilitated the expression of emotional states through various means, including non-verbal communication and real-time feedback. The* ***ambiguity and indirect expression*** *of the emotional state of Emotions2Us make* ***emotional expression easier*** *(5.5.1).* ***After and without Emotions2Us****, people are more* ***comfortable communicating and externalising*** *their feelings and emotions (5.5.2). However, they created a* ***technological attachment*** *with Emotions2Us* ***missing the communication stimulus*** *(5.5.3). Also, emotional states shared between dyads could help* ***health professionals promote more personalised care*** *for stroke survivors' rehabilitation therapies (5.5.4). These features improved emotional expression, promoted dialogue, and reduced emotional burdens within the dyad.*

6 Discussion

In this section, we answer the proposed research questions, reflect on the challenges, benefits, and opportunities of social sensemaking technologies after a stroke, discuss limitations, and describe future work.

6.1 Answering the Research Questions

Does Emotions2Us facilitate the expression of emotional wellbeing? The design approach of Emotions2US promoted survivors' and caregivers' emotional expression through technology. Emotions2Us reflected the combined emotional states of the stroke survivor and caregiver. Since the emotional states of each were reflected implicitly, it lowered barriers to participation and made individuals comfortable doing so. The SAM valence scale [14] combined with TLS used for emotional expression also facilitated the understanding and interpretation of emotional states through colours. Moreover, the interdependency approach to showing the emotional state only after both users participated was reported to promote mutual encouragement and trigger communication about emotional wellbeing. Overall, findings highlight how a shared and interdependent interactive display can make intimate emotional states visible in a stroke survivor-caregiver relationship.

What is the influence of Emotions2Us in wellbeing awareness and social sensemaking? Through increased emotional awareness, dyads could engage in joint sensemaking about their daily actions and how they affected their wellbeing and that of others. Participants reported engaging in self-reflection not just about their emotional state but also showing greater concern for their partner. Communication seemed to be critical in this process. Emotions2Us was reportedly an important trigger to foster communication and empower people to talk about their emotional wellbeing.

After a stroke, most attention is given to the wellbeing of survivors as they are directly impacted by it. Still, research shows that the effects of stroke extend beyond the individual to their caregivers [16, 35, 79, 102]. In our study, we highlighted the emotional state of both stakeholders, encouraging a greater awareness of their mutual wellbeing. Participants, most notably survivors, reported being more attentive to the wellbeing of caregivers and how their actions could have a positive influence.

In summary, findings suggest that Emotions2Us fostered increased (individual and joint) emotional awareness, communication, and social sensemaking, leading to mutual understanding and stronger relationships.

Does Emotions2Us contribute to the dyad's care and support practices? Participants reported engaging in social sensemaking activities when using Emotions2Us, which may foster behavioural changes among individuals [74, 127]. Examples include new communication patterns that lasted beyond the prototype's usage and led to the adoption of mutual care practices [5, 11, 127]. Participants' reports blur the lines between the giver and receiver of emotional support. We acknowledge that such an effect may not generalise to everyone, but our participant sample illustrated how joint emotional understanding can strengthen relationships and share the emotional labour within dyads.

It is important to note that making people aware of their emotional wellbeing is important but not the only factor in promoting new practices [40, 41, 105, 127]. Our findings suggest that social technologies can play an essential role as participants mutually encourage each other to engage with Emotions2Us while building expectations for improving their wellbeing. The social component can be crucial in eliciting and persuading positive change. As told by participants, discussing emotional states and showing concern for others became part of the routine. These are the foundations of emotional care work.

6.2 Design on Social Sensemaking Following a Stroke

Considering the findings presented, it is essential to highlight the importance of **emotional support for stroke survivors and their caregivers**. Previous studies suggest an overall lack of emotional support after a stroke [16, 79, 102]. Thus, it is crucial to explore novel strategies that empower stroke survivors and their caregivers. These strategies can help them by providing support and helping them overcome the practical challenges of their new way of life while simultaneously overcoming stigmas. Creating technology for emotional support and care shows to be a promising research avenue. Most existing technologies and interventions in stroke rehabilitation emphasise physical and cognitive recovery [25, 27, 31, 34, 62, 65, 77, 88, 109, 120], with less attention given to emotional and social wellbeing.

Furthermore, the study highlights the importance of **accounting for the caregiver when considering the effects of a stroke on wellbeing**. Namely, emotional wellbeing is essential for the dyad's recovery and handling life's new challenges after a stroke. The joint challenges that dyads face must be considered, as well as the benefits of including caregivers as a key component of the solution. Emotions2Us has shown that this inclusion is critical, as it has made it possible to promote communication and mutual support between the stroke survivor and the caregiver.

Our findings suggest that **using social sensemaking technologies, leveraging the concept of "wellbeing-as-interaction" [105], can promote joint awareness, communication, reflection, care and possible behavioural changes**. This concept and these technologies have shown that increasing emotional awareness can positively influence behaviour and coping mechanisms, similar to previous investigations [95].

Previous studies have explored technologies to improve emotional awareness and communication, often focusing on individual users [47, 71, 127], other target groups [5, 41, 49, 117] or even dyads [11, 73, 81, 94]. However, most of these works aim to promote awareness and interaction between

dyads at a distance [73, 81, 117], and our case is more similar to those where the dyads are interacting or live nearby.

Some of the works we were inspired by also present differences in approach, basing the sharing of emotional state on neurophysiological signals [40, 105], and the works themselves mentioned that users sometimes tried to manipulate the results by altering the neurophysiological signals themselves. Another approach that has similarities to ours is emotional sharing through colours. The work of Snyder et al. [105], MoodLight, shows, through a lamp, a colour pattern that is based on the heartbeat, corresponding to the arousal, the intensity with which an emotion is felt, which makes it more difficult for the user to interpret the other person's real emotional state, compared to our approach. Also, our approach makes it easier for users to understand and express their emotional state, combining a TLS with a SAM valence scale, scales with which users are more familiar.

Another work, with great similarities, is the one of Rodgers et al. [95], where students' dyad could express their moods through colour animations displayed on their friend's mobile app and an ambient display in their friend's home. In their case, the emotional expression ambiguity came from the colours that each person selects to express their moods and not the combination of emotional state colours. In that way, compared with our approach, the motivation to trigger the communication between dyads is different: in the MoodCloud, the trigger is to understand what mood a colour represents; in Emotions2Us, the communication trigger is more related to emotional awareness, mutual understanding about emotional state and care for the own and the others emotional state, being crucial to dyad social sensemaking. Also, comparing MoodCloud and Emotions2Us, Emotions2Us is only one ambient device where both users interact, and in MoodCloud, each user has one device at home. Furthermore, the promoted communication type differs because Emotions2Us promotes face-to-face communication since users are in the same house and interact with the same device. On the other hand, MoodCloud promotes distance communication since each user interacts with their device and through a mobile app, where they can change messages through a chat, leaving the personal interaction between dyads we intend to encourage.

This way, one of the aspects to emphasise that Emotions2Us bring is **the communication improvement between the dyad and the strengthening of the relationship**. It led to greater concern and care behaviour between people, reducing barriers to discussing emotional wellbeing, feelings, and worries. Emotions2Us has increased openness to emotional sharing, support and mutual care. These changes have modified how the dyads interact and relate, making them more concerned about each other and providing more mindful emotional support [75]. In addition, Emotions2Us created a new family dynamic and encouraged new verbal interactions between the dyad and the family.

Emotional expression plays a central role in Emotions2Us. It is the visible and shared side of emotions, in which the sharing of affection facilitates establishing social relationships [89], so important for dyads' emotional and social wellbeing [16, 102].

Moreover, Emotions2Us can **promote emotional education** by making survivors and caregivers stop and think about and express their feelings in the best way possible. Findings suggest survivors and caregivers were truthful when expressing their emotions through Emotions2Us. This fact shows that **survivors and caregivers felt comfortable sharing their emotional state**, considering the design of Emotions2Us and the approach used to display aggregated emotional states. This facilitated the establishment of routines and the attempt at daily interaction [6].

Sharing the emotional state information collected by Emotions2Us with health professionals could be an interesting opportunity for health professionals to personalise and improve their interventions. At this point, it would be interesting to share it with the professionals who apply rehabilitation therapies to survivors so that they can understand how the survivor feels before

each session and thus be able to adapt the exercises and personalise the session to captivate the patient and get the best possible out of the session. Another aspect could be to share this data with clinical health professionals who provide emotional and psychological support to the dyad. They could share their emotional states and the emotional progress of the dyad to help as an auxiliary tool of emotional support so that clinical and health psychologists could understand and conduct their intervention more efficiently.

Another possible design opportunity is **using Emotions2Us for stroke survivors with aphasia**. Results suggest this could facilitate communicating their emotions with others, especially caregivers.

In summary, our work presents a novel contribution by developing and evaluating a technology that specifically enhances the emotional wellbeing of stroke survivors and their caregivers through an innovative, dyad-focused, interactive ambient display. This approach addresses existing gaps in emotional support and opens new avenues for integrating emotional wellbeing into comprehensive stroke rehabilitation practices.

6.3 Limitations and Future Work

We described a real-world longitudinal deployment of a social sensemaking technology for stroke survivors and their caregivers. Although we provided useful insights on its impact on individual and social behaviours, we focused on qualitative results. Further research with a larger user sample and a randomised control trial design is needed to quantify the influence of Emotions2Us on people's emotional wellbeing.

Furthermore, we recommend that future studies consider potential gender bias to enhance the depth and accuracy of behavioral insights, particularly caregiver gender bias, since our sample was slightly biased towards female caregivers (6 out of 8).

Moreover, the combination of emotional states can have advantages and potential limitations. Display of the combined emotional states can cause distraction or difficulty perceiving the other's emotional states, requiring participants to remember the emotional state they selected to interpret the current state.

Our work focused on the social sensemaking of stroke survivors and caregivers. Although findings related to increased emotional awareness are similar to prior work in the field [94, 127], we do not argue social behaviours are generalised to other user groups and stakeholders. Future studies can consider other social groups and settings as suggested by some of our participants, e.g., couple therapy, classrooms, hospitalised patients, and other caregivers.

7 Conclusion

Our study highlights the important role of social sensemaking technologies in enhancing the emotional wellbeing of stroke survivors and their caregivers. We investigated the potential of Emotions2Us, a social sensemaking technology, to foster emotional wellbeing awareness and reflection among the dyad. We conducted a one-month field deployment of the prototype with eight dyads. Our findings suggest that Emotions2Us, an interactive ambient display, promoted emotional state awareness, emotional expression, and communication within dyads. Also, findings may support the development of coping mechanisms and encourage behavioral changes to improve emotional wellbeing. The deployment of Emotions2Us highlighted the potential role such technologies could play in post-stroke recovery's often-overlooked emotional and social dimensions. By fostering interdependent interactions, Emotions2Us has highlighted the importance of mutual emotional care and support and emphasised the caregiver's key role in this process. Our study contributes to the field of Human-Computer Interaction (HCI) and stroke rehabilitation by presenting a novel approach to wellbeing technologies that consider the dyadic relationship between survivors and

caregivers. This approach underscores the potential benefits of integrating social sensemaking technologies into the daily lives of stroke survivors and their caregivers, providing a foundation for future research and development in this area. In conclusion, Emotions2Us has shown potential in improving how emotional wellbeing is managed and understood in the context of stroke recovery. By supporting emotional expression, awareness, and communication, social sensemaking technologies like Emotions2Us can significantly enhance the emotional wellbeing of both stroke survivors and their caregivers, ultimately contributing to a more holistic approach to stroke rehabilitation.

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