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Analyzing equitable access in a remote socio-enactive setting: A case study

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Abstract Ubiquitous Computing as proposed by Mark Weiser in 1991 creates a huge diversity of interaction possibilities through, e.g., sensors, actuators, physiological data, wearables, to name but a few. Providing equitable access to everyone in these unpredictable interaction environments is already a challenge. Additionally, the Covid-19 pandemic brought new challenges to these scenarios by adding remote interactions. Ubiquitous computing remote environments should provide equitable access to everyone, including people with disabilities. To better understand such issues and contribute to their solution, we studied and evaluated access in the Aquarela Virtual workshop using the UbiAccess evaluation instrument. This workshop offered a remote ubiquitous computing environment within the context of a kindergarten school. We used thematic analysis to understand the interaction needs of an Autistic Spectrum Disorder (ASD) child during the workshop. This paper extends previous research with additional data and its analysis - in particular, concerning information provided by the teacher responsible for the specific classroom, and data on the ASD child contributing to: 1) Reflections about remote ubiquitous environments and equitable access; 2) Benefits of ubiquitous computing interactions as regards the ASD child; and 3) Coverage of the UbiAccess evaluation instrument.

Keywords: Ubiquitous Computing Environments, Universal Access, Equitable Access, Accessibility, Autistic Spectrum Disorder, Socioenactive Systems

1 Introduction

Ubiquitous Computing is a contemporary view of technology that has been evolving during the years. It has become part of our daily lives through wearables, tangibles, Internet of Things (IoT) among other devices. Ubiquitous Computing was idealized to allow a transparent interaction throughout a variety of sensors and devices spread into the environment's surroundings [Takayama, 2017; Weiser and Brown, 1997]. These devices collect and process a huge diversity of data allowing interactions through movements, gestures, proximity-distance, or speech, to name a few. Ubiquitous Computing Environments can be present in a large diversity of scenarios contributing, for instance, to improve learning conditions in schools [Caceffo *et al.*, 2022], healthcare in hospitals [da Silva *et al.*, 2022; Liao *et al.*, 2018], or immersion in museums [Duarte *et al.*, 2019, 2020].

An "in the wild" ubiquitous environment experiment was, for instance, conducted during the 2012 Olympics [Morgan and Gunes, 2013]. It connected a physiological heart beating sensor, a Microsoft Kinect device, a computer, and the London Eye, in England. The participants wore an earring accessory with the sensor and freely moved their arms in front of the Kinect device. The system captured the physiological data to combine the emotions of the participant with the arm movements. As a result, different combinations of colors were exhibited at the London Eye.

New computing interaction possibilities bring the necessity of conducting research to guarantee equitable access to all people, despite their physical, intellectual, or sensorial conditions. The factors dynamically involved with the integration and cooperation across the elements spread in a technological environment need to consider the universal access perspective [Stephanidis, 2009, p. 448]. The term "access", in this paper, refers to the possibilities of encompassing the entire scenario, environment, people, and all objects. The term "accessibility", in this paper, follows terminology adopted by related research — see the work of Colley *et al.* [2022] that conducts a meta-analysis on accessibility in HCI. It refers to enabling individuals with disabilities to have access to an environment and all facilities within it.

Accessibility and Universal Access to technology are one of the worldwide Seven Research Challenges in Human Computer Interaction (HCI) [Stephanidis *et al.*, 2019]. Additionally, Accessibility and Ubiquitous Computing are two of the Brazilian HCI research challenges [Baranauskas *et al.*, 2015]. Although Ubiquitous Computing is a contemporaneous technological concept, the HCI community has still concentrated most of its accessibility studies on web accessibility [Lima *et al.*, 2021]. Our research address on Access and Ubiquitous Computing challenges. Finally, we are aligned to the Sustainable Development Goals (SDG)[1] organized by the United Nations to cooperate to a more equitable world under the perspective *"Leave no one behind"*. Within the 17 goals and 169 targets, the inclusion of disabled people is in the 4th, 8th, 10th, 11th and 17th goals[2]. In our research, we directly collaborate with the following goals: a) 4th goal ("Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all"), through promoting inclusion in school activities; and b) 10th goal ("Reduce inequality within and among countries"), through technological and social inclusion.

Socioenactive Systems are instances of Ubiquitous Computing Environments which dynamically couples the Physical, the Digital and the Social dimensions. Body, environment, and the physical space are examples of the Physical Dimension. The Digital dimension embraces, for instance, the software and the digital media. Finally, the Social dimension involves the people, the society, the cultural milieu, and human values, to name a few [Baranauskas *et al.*, 2021; da Silva *et al.*, 2022]. The concept of Socioenactive Systems has been developed in the Brazilian FAPESP Thematic Project 2015/16528-0[3], within which this research took place. The Project works with three partners: a kindergarten school, a museum and a hospital.

The Covid-19 Pandemic declared on March 12th 2020 by the World Health Organization (WHO) brought new challenges and possibilities of research, alongside the sanitary protocols, restrictions and social isolation. Due to the restrictions instituted by the Pandemic situation, the Socioenactive Project research team developed a system to investigate the challenge of socioenactive interactions in remote scenarios. Our researchers joined in the Open Design[4] platform to work in this challenge around January 2021. All the design process is described and detailed in Gonçalves and Baranauskas [2022]. The "Aquarela Virtual" System is the result of our attempts to create a socioenactive system to be used remotely. It is named after a traditional and culturally well known Brazilian song (apud Duarte and Baranauskas [2022]; Gonçalves and Baranauskas [2022]) aiming to investigate these socioenactive scenarios. We chose this song because of its lyrics, which contain many childhood elements.

We designed the Aquarela Virtual system for a kindergarten audience, creating animations of the song elements (e.g., seagull, castle). As we planned this system at the beginning of the year, we intended to use it in a workshop at the kindergarten school at the end of the year. Two teachers of the kindergarten accepted the idea of sharing a workshop on that. Consequently, they introduced the song elements to the children and worked on the topic of emotions with them. We added to the system emojis that represent emotions and their animations. The children could express themselves to the others using what they learned at the school about expressing their emotions.

The system supports simultaneous connections and the exploration of the song animations, triggered by physical objects containing a QRcode (e.g., a castle, a seagull, a boat, etc.). The system motivated a workshop named after it: *"Aquarela Virtual Workshop"*. This workshop happened at the end of 2021, at the beginning of the flexibilization of the pandemic restrictions. Section 4.2 describes the system and the workshop.

Our objective in this article is to investigate equitable access in the "Aquarela Virtual" System through the thematic analysis of the interactions of an Autism Spectrum Disorder – ASD (kindergarten age) child during that workshop. We describe an evaluation with all the participants and the kindergarten teacher interview. In the evaluation activity we used the UbiAccess instrument [Pimenta *et al.*, 2022c] including the case of Alvaro (fictitious name) a child diagnosed with ASD. We aim to answer two research questions:

> **RQ1:** *Is it possible to identify whether the Aquarela Virtual system, as adopted in the workshop, enables equitable access?*
>
> ***RQ2:*** *Are the UbiAccess areas effective to evaluate access in a socioenactive remote scenario?*[5]

This paper is an extension of the conference paper Pimenta *et al.* [2022b], presenting the following new additional results: a) The kindergarten teacher's interview about the workshop effects on the children, especially as regards the ASD child; and b) The thematic analysis of the ASD child interaction during the workshop, to improve the understanding of access in the studied context. We clarify that the interaction analysis of the child was supported by his kindergarten teacher, who has knowledge about his particular condition and has knowledge about the medical information provided to the school by the child's parents.

The main contributions of this work are: 1) Reflections about remote approach to ubiquitous environments and equitable access, unifying and contrasting related work; 2) Benefits of ubiquitous computing interactions as regards the ASD child; and 3) Coverage of the UbiAccess evaluation instrument.

The paper is organized as follows: Section 2 presents the research domain and some related works; Section 3 presents the methodology; Section 4 presents the Case study; Section 5 discusses the research results, and Section 6 concludes the paper.

2 Research Context and Related Work

According to [Emiliani and Stephanidis, 2005, pp. 606, 612], Universal Access means the access to information technologies by everyone, everywhere and every time. Likewise, there is the necessity of developing methods and technologies to support the design of universal access solutions. Besides, there is a need for supporting tools to design and evaluate these new types of environments. Furthermore, inclusive

[1] SDGs: https://sdgs.un.org/goals
[2] https://www.un.org/disabilities
[3] Socioenactive Systems: Investigating New Dimensions in the Design of Interaction Mediated by Information and Communication Technologies (FAPESP 2015/16528-0) https://socioenactive.ic.unicamp.br
[4] https://opendesign.ic.unicamp.br/
[5] This paper distinguishes between the Aquarela Virtual software and the workshop conducted using the software

design benefits all people who interact in the environment, not only those with special needs, such as people with some permanent disabilities or temporary impairments [Stephanidis, 2009]. As Stephanidis and Antona [2022] argue, the challenges of equitable access are still an open question regarding intelligent technological ecosystems.

In this research we define *equitable access* as the possibility that people, regarding their specific conditions, have access to technologies and technological environments, and should be able to make sense of the interactive experience. Equitable access allows a person to make sense of an interactive experience in the ubiquitous computing environment like any other participant [Pimenta *et al.*, 2022c]. Our findings rely on data on disabilities from the Brazilian National Health Research study[6] supported by the country's Ministry of Health in partnership with the Brazilian Institute of Geography and Statistics (IBGE). The latest available data is from the year 2019, indicating that 1.2 % of the Brazilian population had some mental or intellectual disability.

The pandemic brought new challenges for education and accessibility, with schools being forced to begin remote classes without any preparation. This was increased when dealing with kindergarten children in a remote context. The challenge of addressing equitable access in these scenarios, by extension, was also increased. Furthermore, we as a research community should prioritize inclusion [Hayes, 2020; Wong-Villacres *et al.*, 2022] as a *"truly supportive and inclusive learning environment should prioritize and foster social connections with others"* [Metatla *et al.*, 2018].

2.1 Theoretical Foundations

Universal Design Principles [Connell *et al.*, 1997] are a well known reference when considering Design for All. Such knowledge changes every day, no matter whether we are dealing with, e.g., computer science, house building, or learning tools. The 7 Design Principles are an excellent starting point for considering Design for All. However, they do not cover all the complexity of contemporaneous scenarios of ubiquitous technology, for instance, involving wearables, Internet of Things (IoT), or any kind of smart appliance. In the same context, Takayama [2017] and Weiser [1991] indicate that contemporaneous technology should surround people not as a barrier but as part of social interactions. This comes together with our research approach where the social environment is an integrated and important part of the scenarios. Moreover, in Socioenactive Systems, the Physical, Social and Digital factors cooperate with each other, thereby contributing with new possibilities of interactions [Baranauskas *et al.*, 2021; da Silva *et al.*, 2022].

2.2 Related work

Related work covers many factors, including accessibility in ubiquitous computing environments, collaborative technologies for disabled children, universal access, evaluation instruments and formal patterns. An example of work in the context of ubiquitous computing and disabled people is the DIX (Disability Interaction) movement that has been performing research considering disabilities, impairments, and special needs as innovation opportunities [Holloway, 2019]. The DIX group develops inclusive and assistive technologies, such as a wheelchair that becomes an object of Internet of Things (IoT). The IoT object allows the wheelchair to connect itself to a mobile app that helps to find and map accessible wheelchair streets and places in the city.

Considering collaborative technologies for disabled children, a systematic literature review [Baykal *et al.*, 2020] concluded that the scientific community has given attention to embodied interaction and tangible devices. Additionally, the paper revealed that Autistic Spectrum Disorder — ASD children are a frequent target of the literature.

An investigation of universal access in museums [Hayashi and Baranauskas, 2017] evaluated different museums and observed the need for access from a global perspective: environment, technology and everything that surrounds them. This research also revealed the lack of basic accessibility resources such as tactile floors. Nevertheless, the authors discussed ubiquitous computing environments and socioenactive scenarios which benefit from the Social dimension to create unique interaction experiences.

Regarding formal evaluation patterns and universal access, we point out the work of Gonçalves *et al.* [2020] that analyzed the application of W3C-WCAG 2.0 (Web Content Accessibility Guidelines)[7] in a ubiquitous and pervasive environment. Moreover, Gonçalves *et al.* [2020] analyzed the available solutions in the literature for visual, hearing, and motor disabled people. The results of the research pointed out the lack of specific tools and methods for design and assessment of ubiquitous environments to help in the development of inclusive solutions.

An investigation of a socioenactive scenario used the Affectibility Principles (Paff) to investigate universal access [Santos *et al.*, 2019]. The study took place at a craniofacial hospital with children participants in Brazil. The authors analyzed how affection could help in achieving universal access in socioenactive systems. As a result, the study generated a group of recommendations for interactive artifacts designers considering the aspects of affectibility to promote universal access within these scenarios.

Our analysis uses UbiAccess — an equitable access assessment instrument for ubiquitous environments [Pimenta *et al.*, 2022c]. This instrument should be able to analyze the ubiquitous computing scenario, enacted at the *"Aquarela Virtual"* workshop. The evaluation instrument should be able to cover the Physical (remote and physical environments, toys), Digital (animation of the real toys, emojis) and Social dimensions of the environment. The other instruments we could find [Duarte and Baranauskas, 2022; Santos *et al.*, 2019; Sanderson *et al.*, 2022] did not cover all these requirements. Consequently, we decided to use UbiAccess and investigate its potential in this scenario. The instrument is based on the guidelines of the Universal Design Principles [Connell *et al.*, 1997] and the guidelines and success criteria of W3C-WCAG 2.1 for ubiquitous environments. The instrument had been previously used to evaluate two installations at a museum in

[6] Pesquisa Nacional de Saúde (PNS) – National Health Research: https://www.pns.icict.fiocruz.br/painel-de-indicadores-mobile-desktop/

[7] https://www.w3.org/TR/WCAG20/

Brazil [Pimenta *et al.*, 2022c]. The study of Sanderson *et al.* [2022] evaluated the knowledge of faculty members in accessibility guidelines to apply them in the development of learning materials in computer science. The results showed the lack of knowledge in these formal patterns and the need for knowledge regarding practical application of accessibility guidelines to develop more accessible digital learning materials and courses. Another study [Duarte and Baranauskas, 2022] used thematic analysis to evaluate a remote workshop on ubiquitous computing. The study analyzed how children could remotely interact among themselves and with the system. The results pointed out the benefits of embodiment and social interactions even in remote interaction environments. Furthermore, socio-affectivity, communication, autonomy and socio/group identification also appeared in the remote interactions.

Acknowledging the aforementioned related work, our results involve the following subjects: 1) Contemporaneous computational technologies for disabled people [Baykal *et al.*, 2020; Holloway, 2019]; 2) Accessibility or universal access in ubiquitous and pervasive environments [Gonçalves *et al.*, 2020; Hayashi and Baranauskas, 2017; Pimenta *et al.*, 2022c; Santos *et al.*, 2019] 3) Formal evaluation accessibility principles in ubiquitous computing environments [Gonçalves *et al.*, 2020; Pimenta *et al.*, 2022c; Santos *et al.*, 2019]; and 4) Thematic analysis of research data involving the Covid-19 pandemic context in computing [Pimenta *et al.*, 2022a; Sanderson *et al.*, 2022; Duarte and Baranauskas, 2022]. Our work unifies these subjects by contributing to the issues of equitable access evaluation of ubiquitous environments. It addresses a case of an ASD child interaction in a remote ubiquitous computing scenario. Moreover, we use thematic analysis to study the interaction of the ASD child and advance on the perspective of remote interactions leveraged because of the Covid-19 pandemic. Finally, we raise considerations for inclusion of disabled people in remote scenarios of interaction by evaluating the extent of equitable access in the ubiquitous scenarios.

3 Methodology

In this work, we analyzed the interaction of kindergarten children during the *"Aquarela Virtual"* workshop, including the recordings of the interaction of the ASD child. In addition, we also considered the activities of his teacher. *"Aquarela Virtual"* is a System developed within the context of the Socioenactive Project (c.f. Section 1). This system was used in a workshop held at a school, enacting a remote interaction scenario, detailed at Section 4.2. Our methodology covered two stages: 1) Activities with questions based on UbiAccess areas (c.f. Section 3.1) with answers from the Teacher and from Children; and 2) Thematic analysis, generating the Thematic Map of the Video Transcription. During these stages, we could identify the coverage gaps of UbiAccess areas and start eliciting the gaps in access for the ASD child. This analysis was conducted with support from the teacher, who is familiar with the ASD child and has information on his disability provided by his family. Finally, we highlight results about equitable access in remote ubiquitous scenarios. Figure 1 illustrates the methodology of our qualitative study.

3.1 The UbiAccess Evaluation Instrument

The UbiAccess instrument[8] is a result from our previous research [Pimenta *et al.*, 2022c]. We chose our own instrument because we could not find any other access evaluation tool for ubiquitous scenarios (c.f discussed in section 2). Although W3C-WCAG (World Wide Web Consortium - Web Content Accessibility Guidelines) promises to cover wearables, it is still in a draft version. Moreover, we also want to understand the application of our instrument in a remote scenario of interaction. The instrument is based on the Universal Design (UD) Principles [Connell *et al.*, 1997] and W3C-WCAG 2.1 (the latest stable version when the instrument was created). UbiAccess has five evaluation areas [Pimenta *et al.*, 2022c] as presented in Figure 2.

1. **Environment (EN)** — physical environments and their surroundings.
2. **Information (IN)** — content and information.
3. **Multimedia Resources (MR)** — text, audio, and video resources.
4. **Personal (PE)** — personal needs and preferences.
5. **Security & Privacy (SP)** — security, safety, and privacy.

We believe that these five areas may enlighten equitable access in the remote *"Aquarela Virtual"* workshop, our investigation target. Besides the five areas, UbiAccess contains a total of 37 recommendations identified by two letters corresponding to the area, followed by a sequential number (e.g., PE1 is the first recommendation of the Personal area; SP3 is the third recommendation of the Security & Privacy area etc.).

UbiAccess was previously used in the evaluation of artifacts of ubiquitous computing scenarios [Pimenta *et al.*, 2022c] in face-to-face scenarios, allowing an evaluation of equitable access and generating improvement on recommendations. Continuing the research, we used UbiAccess Areas to evaluate Access in the "Aquarela Virtual" workshop to answer RQ1 and RQ2 [Pimenta *et al.*, 2022b] here extended to include additional analysis results.

3.2 Question-Based Activities

We held the *"Aquarela Virtual"* workshop on November 5th, 2021. We used Google Meet to talk to the teacher on November 25th, 2021. Subsequently, we talked to the children during a semi-structured group interview on December 2nd 2021. The distance between the activities (workshop and interview) was due to the availability of the teachers, as the school has a calendar to follow. We minimized this time gap by presenting pictures and videos to remind the participants of the experience during the workshop. The UbiAccess based questions were the main guide to the activity. Moreover, new questions were raised during the activity.

Three researchers interacted with the teacher in the post-workshop question-answer activity, using the following questions based on UbiAccess:

[8] The UbiAccess instrument is available to use at Pimenta *et al.* [2023]

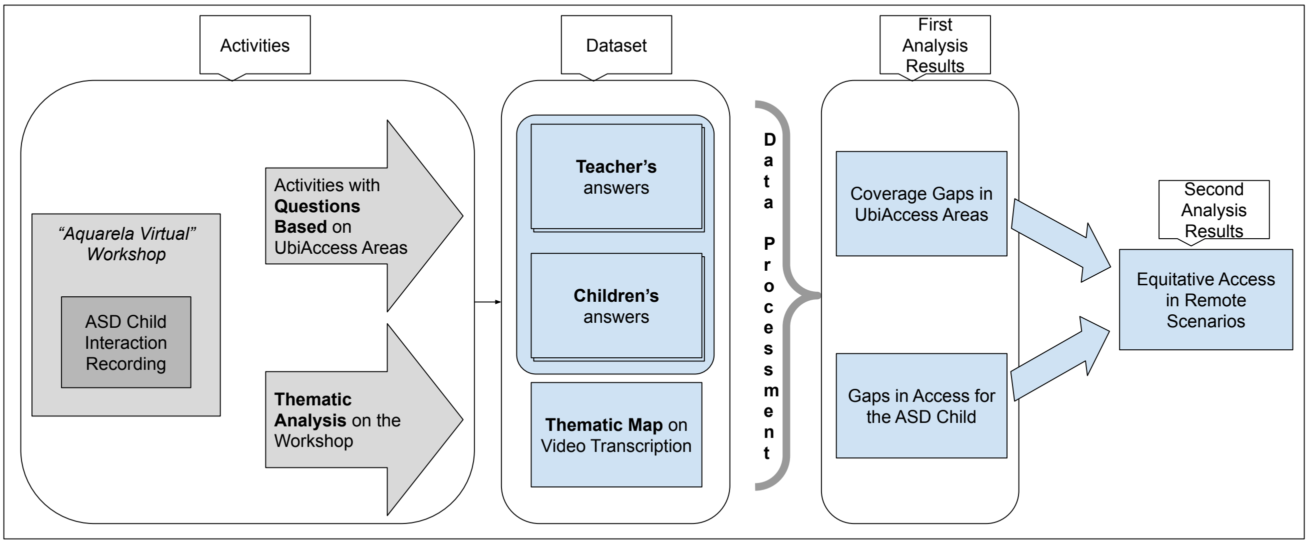


Figure 1. Main steps of the study methodology, which single out activities (workshop and subsequent analysis). These activities generated three main datasets, subsequently analyzed, producing several kinds of results.

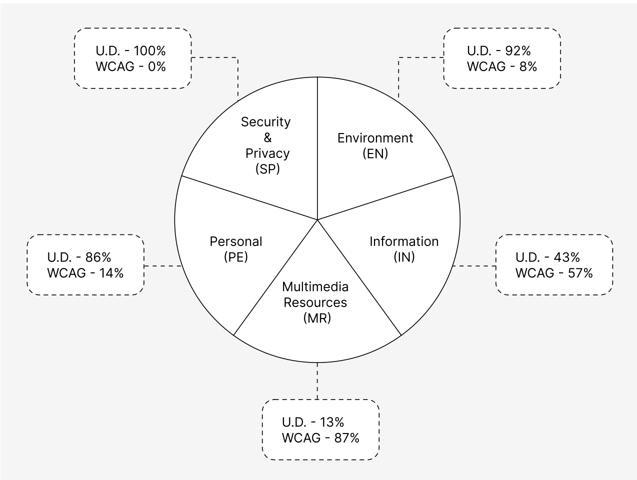


Figure 2. UbiAccess areas — reproduced from Pimenta *et al.* [2022c].

1. What did you notice that involved the children and aroused their curiosity in the workshop? (Areas: Personal, Information, Environment);
2. What difficulties did you identify that the children had during the workshop? (All the areas);
3. What suggestions for improvement would you indicate for the Workshop or for the system? (All the areas);
4. Do you have any additional comments? (All the areas).

The activity with the children who participated in the workshop was conducted on December 2nd 2021, led by two researchers: one *in loco* and the other remotely connected through the Google Meet platform. The activity was conducted in the school where the workshop took place, and followed all the sanitary protocols regarding Covid-19 security.

We rearranged a classroom to increase space, e.g., removing chairs. A laptop connected with the internet was on a table, positioned so that its built-in camera could record the participants. In front of the participants, a projection screen received the image of a projector, showing the Google Meet video of the remote researcher. The participants and the other researcher sat on the floor. We placed two cameras in the room: one in the side of the screen and the other close to the laptop — Figure 3 shows a photo taken while the activity was being conducted. On the left side, the participants are sitting on the floor looking at the screen. On the right side, we see all the participants with the researcher. Notice that all participants wear masks — for sanitary reasons, but also for ensuring their privacy.

This activity lasted 24 minutes. In order to create a more ludic environment with the children, the researchers conducted a presentation activity. First, we invited the children to sit in the center of the room. Then, the researchers and the children introduced themselves. As the majority of the children were dressed with superhero clothes, each one received a nickname: Spider-Man – Álvaro, Captain America – Paulo, Flash – Hebert, Flower SuperHero – Luana and, Super Rainbow – Letícia[9].

Figure 3. Evaluation activity with the Aquarela Virtual workshop participants.

Álvaro is the ASD child who was part of the study. Although the children enjoyed sitting on the floor, Álvaro chose to sit on a chair, close to the group. We sat in a semicircle, to leave an open space to include him on the chair. The teacher sat on a chair close to Álvaro, to provide him a more comfortable environment and allow him to freely participate.

Since the activity occurred some days after the workshop, we presented to the children the pictures of the Aquarela system, of the children themselves and of the workshop mo-

[9]We used fake names to preserve the children's identities.

ments. This presentation aimed to make the children remember their experiences at the workshop. Furthermore, this also allowed us to capture relevant comments to investigate access. In the sequence, the researchers created a dialogue with the participants and introduced the questions in a ludic way. Although we planned just the four following questions, they were adapted in real time according to the subjects that were raised by the children while answering the questions. All the results are presented in the Results section. The questions originally planned were:

1. What did you enjoy the most in the workshop? (Personal and Environment areas);
2. What did you not enjoy in the workshop? (All the areas);
3. What did you think was difficult to do? (Multimedia Resources, Information and Environment areas – capturing the gaps in access)
4. Who participated with you in the workshop? (capture the social perception of the children in the remote scenario)

3.3 Thematic Analysis

We based our analysis on the Thematic Analysis, which is a qualitative method used in psychology studies [Braun and Clarke, 2000] and in computer-usage studies [Duarte and Baranauskas, 2022; Sanderson *et al*., 2022].

Our thematic analysis consisted of: 1) transcription of the video recording; 2) analysis of each piece of transcription, which was annotated with one or more codes representing that transcription; 3) grouping the related codes, thereby creating the themes; 4) repeating steps 2 and 3, in successive analyses, to produce at the end the refined consistent thematic map. More on Thematic Analysis is presented in the next section.

We transcribed 29 minutes and 59 seconds. We found 439 codes and 29 themes. This resulted in the Thematic Map that we discussed later in the next sections.

4 Case Study

This section describes the case study, with its context and participants (section 4.1), the Aquarela Virtual system and workshop (section 4.2), and the results of analysis of interaction with focus on a child with ASD diagnosis (section 4.3).

4.1 Context and Participants

This case study involves the workshop held with kindergarten children at DEDIC - UNICAMP (the university's kindergarden and elementary school for children of staff)[10]. This research was part of the Socioenactive Project, which was approved by the Unicamp Ethical Committee (CAAE 72413817.3.0000.5404). All the children signed the Term of Informed Consent, adjusted according to their age. The persons legally responsible for the children also signed the corresponding term. The Socioenactive Project team developed the system and organized all the activities involved.

Participants of the workshop were children between 5 and 6 years old. The whole class was organized in three groups, containing around four to six children. All the groups were accompanied by the teacher. This case study evaluates specifically the second group (Figure 4), where Álvaro participated.

Figure 4. Alvaro (ASD case) participating in the Aquarela Virtual workshop.

We now describe the case of Álvaro with the information obtained from his teacher. Real names have been replaced for privacy reasons. His teacher provided us with the information on Alvaro available in the school. The pedagogical team reported to us that although they do not have access to the level of the ASD, the diagnosis is supported by a medical report, according to the parents. The teacher analyzed the child, comparing his behavior during the experiment with his reactions during the regular school routines and activities, which she closely follows. Her remarks about the child's behavior were thus used by us not only because of her familiarity with the child, but also because she is the pedagogic professional responsible for his teaching.

> *This is a Brazilian family. The child's family is composed of the father Manoel, the mother Vanuza and two children, Ezequiel who is a pre-adolescent and Álvaro who is 5 years and 10 months old. Both children have an ASD diagnosis and study in different schools.*
>
> *He is medicated and under occupational therapy. Álvaro has studied full time since kindergarten. His mother, Vanuza, works in the health field, at a hospital; Álvaro has participated in a few remote activities since the beginning of the Covid-19 pandemic in 2020. From October 2021 onwards, he returned to school and became familiar with teacher Gabriela and colleagues; he was in a new class due to becoming older. Teacher Gabriela reported that Álvaro has a close friend in the class, Paulo. She also said that Álvaro is often afraid of new experiences, usually using the phrase "I don't want". On November 5th, 2021, Álvaro participated in his first experience at the Virtual Aquarela Workshop, together with his teacher, his friend Paulo (remotely) and his friend Helena (remotely). Afterward, his parents told the teacher about the boy's enthusiasm, who, in addition to not wanting to leave home on the day of the workshop, was excited about the other days of classes to come.*

[10] http://www.dedic.unicamp.br/

4.2 Aquarela Virtual

This section describes the workshop and the system. The workshop happened at DEDIC using separate rooms, in Campinas, São Paulo, Brazil on November 5th, 2021. At the time the experiment was conducted, Brazil was in a transition from total remote scenarios to restricted scenarios. Figure 5 presents the layout of the rooms where the workshop took place. The scenario was organized in three separate rooms at the school. Each room had a laptop and some toys. These toys are part of the elements of the song, animated on the screen. The teacher elaborated an activity involving students and their families to build each toy. Furthermore, 08 researchers interacted remotely (six from São Paulo - Brazil, one from Peru and one from Ceará - Brazil), each one at their homes, while others were facilitating the interaction with teachers and children in the physical rooms.

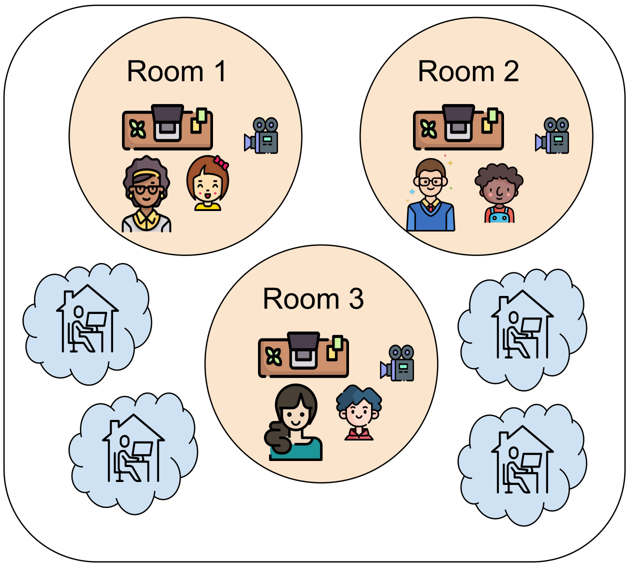


Figure 5. Aquarela Virtual workshop layout.

Each child was accompanied by an adult, either a researcher or their teacher. Each room contained a laptop running the *"Aquarela Virtual"* system and Google Meet, while the child's toys were over a table. A camera recorded all the interactions. The other researchers participated from their homes, observing and talking to the children via Google Meet. We used Google Meet to stay connected by video and audio. This technology was chosen because it is the one adopted and fully supported at our university.

The *"Aquarela Virtual"* system design is detailed in [Gonçalves and Baranauskas, 2022]. The system requirements and development are detailed in [Duarte and Baranauskas, 2022]. Details about all the planning and investigations about equitable access are available in [Pimenta *et al.*, 2022b,a].

The *"Aquarela Virtual"* system projects animations that represent the toys built by the children and some at the school and some with their families. The six animated elements from the song are: sun, seagull, drop of paint, castle, boat, and plane (Table 1). These elements come to life with the animations and the background of the song. Each animation was related to two toys. Whenever a child showed their toy QRcode to the webcam, all the other children could see the corresponding animation, the children's avatar, and listen to the lyrics of the part of the song that talked about that object. These physical objects were built with a partnership between the school and the children's parents (Figure 7 – left). We used QR codes to make the computer camera to identify the objects. Each animated object had a proper QR code fixed on its surface. The children also had their avatars, represented by animals. In the first system screen, the participants put their names and chose an avatar. Figure 6 presents the login screen and the boat animation. Whenever a child shows a toy QR code to the camera, if it is the same element as the actual animation, all children's avatars are shown, representing that the children are together. Figure 7 (left) shows the toys made by the children (at home or at school). Figure 7 (right) shows the castle and sun animation, with the participant showing the sun QR code to the laptop camera. In the animation, three children are participating, represented by the Gorilla, Cat, and Panda avatars.

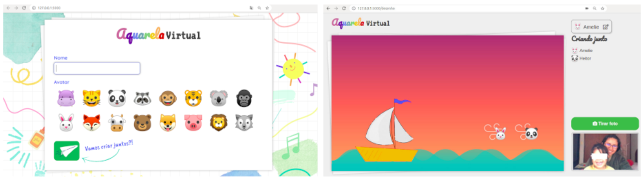
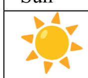
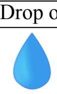
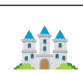
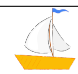


Figure 6. Aquarela Virtual System (Left — Login; Right — Boat animation).

Figure 7. (Left) Children's toys made with their families or at school and the QR codes; (Right) Castle and sun animation with three avatars showing the participants.

Table 1. Toys and corresponding animations [Duarte and Baranauskas, 2022].

Sun	Seagull	Drop of Paint	Castle	Boat	Plane
					

Six emojis allow children to express their emotions: happy, calm, angry, sad, sleepy, and scared (Table 2). These emojis reflect a preliminary work made by teachers with the children about the emotions. These emojis (Figure 4 – right) are physical objects with a QR code. Whenever a child presents the emoji, the system exhibits an animation in the children's image. The other participants see the emoji together with the child's name.

Table 2. Emojis and respective emotions in "Aquarela Virtual" [Duarte and Baranauskas, 2022].

Emotion	Happy	Calm	Angry	Sad	Sleepy	Scared
Emoji						

The *"Aquarela Virtual"* workshop represents a scenario of a remote socioenactive environment. The Physical dimension contains the laptop, the room, the toys, the emojis; The Digital dimension covers the internet, the Google Meet session, the Aquarela Virtual System; and the Social dimension is represented by the children and adults in the same space, but also researchers remotely present in different places.

During the workshop, children could talk among themselves and the remote researchers through the Google Meet. The children freely explored Aquarela Virtual, took pictures through the system picture button, and interacted with their friends. At the end of the experience, the song is played while showing all the pictures taken by the children

4.3 Results

Given the pre-elaborated questions based on UbiAccess areas, we could develop a conversation following up many aspects of the workshop experience, equitable access, and the interactions. We report below the teacher's points of view, organizing them according to the addressed questions.

Considering the subject of difficulties, Teacher Gabriela reported she had not any difficulty, and no barriers to access the system. The children felt comfortable, especially because they could experiment and experience the workshop. There were no right or wrong answers, making them feel free to enjoy the experience. Additionally, the children realized they could use the toys they built to stimulate the Aquarela Virtual, thus becoming, thus becoming very satisfied with the interaction. The experience elicited positive and meaningful learning for each child; this included not only the workshop but all the involvement of the families, the school, and the researchers that conducted the workshop.

We now analyze Álvaro's case. He blocks himself from new situations and fears experimenting new things. Usually, in new situations, he stares at the teacher for a while. Then, the teacher talks to him, explains what the situation is and encourages him to experiment. To avoid this during the experiment, To avoid this during the experiment, the teacher prepared him previously for the workshop and explained that he could leave or not participate at any time. She also allowed him to invite a friend to make him feel more confident. Since the child asked her to stay with him, she remained at his side during the whole workshop, encouraging him and offering encouragement. In the beginning of the workshop, Álvaro asked about his friend, and she showed him Paulo at Google Meet. Even though he saw his friend on the screen, he turned around many times to search for the friend behind him. After the workshop, she said that Álvaro was enchanted with everything. He did not want to go home and said to his Mom it was too early to leave. Finally, the feeling of interacting with the system with something he built with his family also offered good things for the child.

To present the results from the activity, we identify the children as: Álvaro (C1), Paulo (C2), Herbert (C3), Luana (C4), and Letícia (C5). All the transcriptions literally kept the children's speech, which we tried to preserve in the English translation. The original transcription in Portuguese is available at [Pimenta *et al.*, 2022b], which is extended by the present paper.

Table 3 (see Appendix A) presents the questions and answers of the children. During the photos' presentation, children spoke and moved, an excerpt follows:

C2: "I am the fox."
C3: "I am the cat."
C4: "I am the koala"
C2: [when he sees his friend's picture,
he points to C1 and says:] "Álvaro! Álvaro!"
C2: [after seeing his friend's photo again:]
"See Álvaro again!"
C3: "Look! Who is this?"
C2: "This is Álvaro."
C5: "Álvaro, it is you with the teacher."
C1:[holds his arms in the chair and moves his
legs back and forth while looking at the screen.]

Álvaro participated in the activity together with his classmates. Despite not responding directly to any question, he answered with words and gestures when the others made some reference to him (e.g., "No.") when his teacher asked him the questions.

In question #3 "Did you make something with the castle?", Álvaro responded "No.". We revised the recording and identified, as present in Figure 5 – left, that he used the castle during the interaction. We revised the recording of the interaction and the teacher's interview. We observed that the castle was big, and it was closer to the teacher than to the ASD child. In addition, the child had to ask the teacher to give him the castle to show it to the system. Based on that, we recommend that the interaction artifacts be put closer to the children's movement area.

We could also observe that Álvaro could make sense of the experience, as in question #10 *"Was that boat on the water ours?"* he answered with a gesture saying yes. Moreover, during the workshop and the post activity, we noticed that Álvaro expressed himself by balancing his body or legs when he likes something. This happened during the photo's exhibition and at question #17 "Does everybody understand what was there?". In this sense, it is possible to observe that the experience was enjoyable for him, as related by the parents and the teacher.

Figure 8 presents the Thematic Map generated through the Thematic Map generated through the thematic analysis of Álvaro's interaction recording. Despite Álvaro's behavior of blocking himself from a new experience, the child showed curiosity for 7 times and distraction only for 4 times. The child also explored the Aquarela 36 times, which shows that he explored Aquarela quite frequently along the workshop. Cultural aspects were manifested by the child 13 times. It is worth noting that the theme with most occurrences is the teacher-child Local intersubjectivity (143 times). Since an ASD subject might have some communication issues, this occurrence indicates that the child was feeling comfortable. The child also presented some body behavior 52 times and

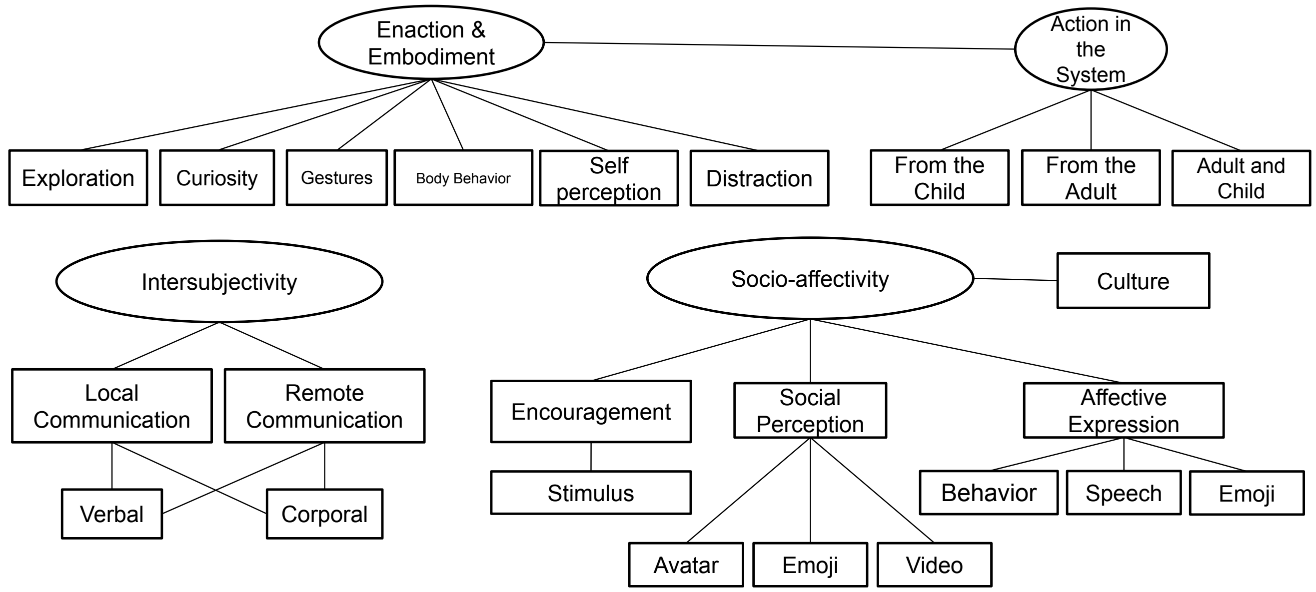


Figure 8. Thematic Map from Álvaro's Interaction.

expressed affection 37 times. The body communication using Gestures occurred 33 times. The Remote Communication happened 31 times. Finally, the teacher encouragement occurred 26 times. As the child interacted with the system for 31 times, summing up with the teacher's answers, we can understand that the interaction of the teacher facilitated the child's comfort.

As presented in the Thematic Map (Figure 8), the four main themes emerging from the interaction are Enaction & Embodiment related to the Actions in the System. Álvaro could make sense of the experience, as we can see him showing the castle to "Aquarela Virtual" (Figure 4 — left). He also showed curiosity, a sub-theme of Enaction & Embodiment, when he was choosing his avatar and he asked the teacher if the gorilla was strong. Later in the conversation, the child asks about the other avatars presented in the login screen, trying to understand which is the strongest animal. Other two important main themes are Intersubjectivity, especially meaningful in the ASD case. The child could interact locally and remotely in the workshop and in the group activity. He used both Verbal and Corporal interactions. Finally, Socio-affectivity's main theme could enlighten the importance of the child's preparation for the activity, making him feel comfortable and encouraged during the activities. The ASD child showed the social perception in the remote scenarios by looking for his friends and paying attention to the remote researcher. The themes were also observed in the video of the group activity held after the workshop.

5 Discussion

Let us return to the research questions of this work, considering first ***RQ1:*** *Is it possible to identify whether the Aquarela Virtual system, as adopted in the workshop, enables equitable access?* The interview answers regarding the areas addressed by UbiAccess show that yes, it is possible. All the children, through their answers, indicated that they were able to participate and make sense of the workshop, e.g., C3 says *"When I showed the boat, it showed the boat on the water."*; C2 says *"We liked it."*; C5 says *"We played."*). The teacher's report also mentioned there were no access barriers or difficulties for the children. Moreover, the teacher reports that the preparation of the ASD child also increased his confidence. The thematic map synthesizes the main elements raised along the interaction (the themes and main codes), especially "encouragement", for the ASD child.

Let us now consider ***RQ2:*** *Are the UbiAccess areas effective to evaluate access in a socioenactive remote scenario?* Here, we observed that the five areas brought a view on equitable access in a ubiquitous environment in the remote context, as for example with question #12 *"Was it difficult to show your toy to the Aquarela Virtual?"*; this question refers to reading the QR codes and covers the areas Multimedia Resources, Information, Environment, to which the children answered "no". Another example involves questions #18 and #19, related to the Personal area, which asked the children if they liked the experiment, and the answers were positive for both questions. Nonetheless, both the teacher report and the Thematic Map indicated that UbiAccess did not cover all areas adequately. For instance, the Enaction & Embodiment of the children giving meaning to the toys and perceiving them as part of the "Aquarela Virtual" are not adequately covered by UbiAccess. This aspect regarding the Socio-affectivity theme remains uncovered by UbiAccess areas.

With regard to the theoretical framework, the socio-enactive aspects emerged in: 1) relationships with the group, when the children realized that their friends and researchers participated in other (virtual and presential) (virtual and presential) places and played with them (e.g., C3 says "There was, but they didn't appear."; C5 says "Popcorn gang!"; C3 says "No, they were big people… they were adults."; C4 "They were adults."); 2) cultural aspects such as the "popcorn class", which is the nickname of one of the school's classes that participated in the workshop; 3) affectivity, through enjoying the activity; and 4) Embodiment, which is perceived through the statements related to playing and playing with peers e.g., C3 says "We were playing."), as well as the perception that the animation was, in fact, their toys. Thus, the evaluation also revealed the need to add other areas to UbiAccess, namely, the Social, to explain access in terms of intersubjective relationships, which are a fundamental part of socio-affectivity and socioenactive interactions.

6 Conclusions and future work

This work addressed the issue of access in ubiquitous environments based on computational technology. The case study presented showed a preliminary analysis of equitable access in a scenario of remote interaction with a socioenactive system. The analysis focused on a group of children interacting with the Aquarela Virtual (Virtual Watercolor) system, and included a child diagnosed with ASD. The analysis used the UbiAccess evaluation instrument. Although this instrument was designed for face-to-face scenarios, it proved to be effective in assessing some aspects of equitable access in remote environments, while lacking others. This case study also pointed out the need to include other areas in UbiAccess, especially related to the Social aspects of interaction in the scenario proposed by the system.

One of the study limitations is related to the lack of interaction of the researchers with the ASD child and his family. This interaction would bring greater comfort to the child during the assessment activity, and could provide better information about system elements being in compliance or not with their more specific situations. Direct interaction with children with ASD could provide more information to the study. However, children with ASD require a period of adaptation to establish bonds with new people. Thus, this adaptation phase could interfere with the analysis; alternatively, we might need to implement an adaptation process before conducting the evaluation. This is something that could be explored in future research through a longitudinal study involving a larger sample of children with ASD with the same level of support. Another limitation refers to the time to schedule the activities for analyzing access, especially with the children. Finally, an activity with the families expressing their considerations about the effects of the workshops on their children would address relevant information to better understand the importance of providing remote interactive activities for all. A final limitation was that we had to conduct the evaluation with the children a month after the workshop, because of the school calendar, while it should have been ideally conducted much closer to the actual workshop. In order to mitigate this limitation, we provided a recalling section with pictures and children interactions in the beginning of the evaluation activity. We started the activity only after reminding the children of what had happened in the workshop.

Future work involves studying the participation of children with vision or hearing impairments, required for a broader assessment of access. Also, desirable are ethnographic studies within the school context, aiming to deepen the understanding of which elements of the computational system can favor the participation of all, including children diagnosed with ASD, in ubiquitous computing environments. In addition, there is a need for revisiting the UbiAccess instrument in socioenactive perspectives and improving the coverage of the missing points and areas. Although the instrument proved itself capable of evaluating ubiquitous computing scenarios, it still needs complementation of particularities of ubiquity (e.g. sensors, actuators). Moreover, the tripartite of a Socioenactive System (Social, Physical and, Digital) might be more explored inside UbiAccess to cover the richness of interactions among these scenarios.

Declarations

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Authors' Contributions

EFD and MCCB contributed to the conception of this study. EFD, MCCB and JROGP performed the experiments. CMBM helped writing, reviewing and editing and provided comments for discussion. JROGP is the main contributor and writer of this manuscript, with the supervision of MCCB. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The specific dataset of UbiAccess is available at Pimenta *et al.* [2023]. Further datasets related to the Socioenactive Project and "Aquarela Virtual" are available at the REDU – Unicamp Research Data Repository[11]

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A Appendix

Table 3. Questions and answers from the children's activity

#	Question	Children's answer
1	What were you doing?	C3 "We were playing"; C4 "No, we were making a thing at the computer."
2	What did you do at the computer?	-
3	Did you make something with the castle?	C1 "No."; C2, C3 "I did"; C3 "I made a castle with hard paper… colorful and hard paper."
4	Why did you make the castle?	C3 "It is from the activity that has the computer and the design".
5	When you show the castle to the computer, did you listen to something?	C2, C3, C4, C5 "Yes!"
6	What else was there? A boat?	C4 "Seagull… watercolor…" C3 "Plane, castle…"; C2 "Boat…"; C4 "Sun"; C3 "Plane, sea…"
7	Were there other people on the computer? Who were these people?	C3 "There were, but they didn't appear"; C5 "From pipoca's class"; C3 "No, there were big people… there were adults."; C4 "There were adults."
8	There was a castle. Does this castle have something you had to show to the computer? Was there a QR code to show to the screen?	C3 "Yes, you showed it to the camera and I learned to take pictures."
9	What happens when you show this QR code to the screen?	C3 "It showed what we show, it appeared a picture"; C3 "When I showed the boat, it showed the boat on the water"
10	Was that boat on the water ours?	C3 "Yes."; C5 "Mine too."; C4 "Mine too"; C2 "Yes"; C1 balanced his head affirmatively.
11	The things you took to the workshop (castle, seagull) were small or big?	C3 "They were big."; C4 "Big"; C2 "Big".
12	Was it difficult to show your toy in the Aquarela Virtual?	C3, C4 "No."
13	Was that easy?	C2, C4 "It was."; C3 balances the head affirmatively.
14	What did you have there? Was there color, design?	C4, C2 "There was color."
15	Was it easy to see these colors?	C4 balances the head affirmatively. C3 "It was easy."
16	Was it possible to understand the designs that were in the computer?	C4 balances the head affirmatively. C3, C2 "Yes."
17	Does everybody understand what was there?	C1 holds his arms on the chair, gets up and balances his whole body.
18	Was there something you didn't like?	C2 "We liked it."; C3 "We like!"; C5 "No."
19	Did you like everything?	C4 balances the head affirmatively.
20	Besides the adults that were there with you, who else participated in the workshop? Wasn't there any friend of yours?	C3 "Ahhh… I don't know… I don't remember."; C4 "Sophie was there."; C5 "We played."
21	There were friends of yours on the computer?	C4, C5 "There were."
22	Were they on your side or in another place?	C3 "They were in another place."
23	How there were people in other places and you could see them?	C3 "It is because there was a camera."
24	And the camera recorded everybody?	C3 "Yes."