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The ecosystem's involvement in the appropriation phase of assistive technology: choice and adjustment of interaction techniques

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Abstract. Designing assistive technologies for the benefit of a population of multi-disabled users living in specialized care homes involves the implementation of a user-centered approach (UCD). The purpose of this article is to demonstrate how the ecosystem also plays a key role in the codesign and appropriation phases of a augmentative and alternative communication (AAC), mainly in the choice and adjustment of interaction techniques through a case study. Firstly, we present related works on the codesign of assistive technologies. Then, we will describe the SoKeyTo platform used for the codesign by the human-computer interaction team. We will also explain the collaboration between the ecosystem and HCI team during tests (place of the switch and type of scanning). Usability criteria were used to determine these choices. Finally, we will illustrate our approach in the codesign and appropriation activities of layout and interaction modes of the AAC.

Keywords: Codesign, appropriation, AAC, ecosystem, multiple disability

1 Introduction

Designing assistive technologies for the benefit of a population of multi-disabled users living in specialized care homes involves the implementation of a user-centered approach (UCD) of Norman [1] and the ISO, I. 9241 [2]. Guffroy *et al.* [3] have introduced the "*ecosystem*" as the social environment involved in the design of assistive technologies. This ecosystem is made up of family and/or professional careers, friends, and colleagues in relation to his or her professional activity, who are involved in the activities of the person with a disability. For people with communication impairments (little or no written and oral language), the participation of ecosystem members is essential in order to design assistive technologies that takes into account the context of use and the expression of needs, see Guffroy *et al*. [3], Derboven *et al*. [4]. In addition, these disabled persons need assistive technologies to communicate with their caregivers and their family. For them, people's needs and preferences are unique and often complex. As they have difficulties to participate themselves in the design activities, our approach is to integrate their ecosystem in UCD activities.

In a first work, Vella *et al*. [5] have integrated clinical data in place of the needs expressed by the end user himself/herself in addition to those given by the ecosystem. The purpose of this article is to demonstrate how the ecosystem also plays a key role in the codesign and appropriation phases of a augmentative and alternative communication (AAC), mainly in the choice and adjustment of interaction techniques through a case study. Firstly, we present related works on the codesign of assistive technologies. Then, we will describe the SoKeyTo platform used for the codesign by the human-computer interaction team. We will also explain the collaboration between the ecosystem and HCI team. Finally, we will illustrate our approach in the codesign and appropriation activities of layout and interaction modes of the AAC

2 Related work on codesign

The UCD approach assumes that end-users are in the best position to express their needs, participate in the design, evaluate and use the interactive system to the satisfaction of the needs and requirements expressed by the users. As a result, these activities encounter implementation difficulties when designing systems dedicated to people with disabilities (communication disorders, motor disorders, cognitive disorders, etc.) according to Antona *et al*. [6]. Indeed, communication and/or cognitive impairments limit the participation of these end-users in codesign.

Kleinsmann [7] defined the codesign as a process in which actors from different disciplines share their knowledge about both the design process and the design content. This is an interesting approach to engage those who will be directly or indirectly affected by the design. Moreover, for Apper [8], there are four principles to consider when designing technologies for people with special needs: "*deep engagement, interdisciplinary, individuality, and practicality, should be reflected upon at the projects' inception and throughout its development cycle*". In a study on codesign in assistive technology, Luck [9] shown that it was critical to engage users in the design process.

Sitbon & Farhin [10] reported that engaging users with intellectual disability in an hour-long codesign workshop with a carer confirm the benefits of digital prototypes, contribute a better understanding of the role of proxies, and suggest a longer engagement to potentially take advantage of co-development.

Hendriks *et al.* [11] raises the question of the positioning of the participants' impairment in the codesign project "*How was the impairment addressed in the interactions during the codesign process? Were the participants involved in the configuration of the codesign process itself*?*"*

Gibson *et al*. [12] have studied on how to better support adults with mild Intellectual disabilities to engage in codesign. Firstly, they conducted a review literature to identify research techniques that have been employed to codesign. One of their outcomes recommend a variety of experts "*the experts had to have five+ years' experience working with or caring for the target population i.e. individuals who adhered to the ID*" [12] be employed within the focus groups to ensure design tasks are approached from different viewpoints and the optimal number of accessibility barriers are addressed before implementation with target stakeholders. Moreover, we think that the entire ecosystem

has to be engaged in the design process. We will describe our approach of taking into account the ecosystem and the person with a disability in the codesign of an AAC.

3 The SoKeyTo platform

We have an interactive SoKeyTo application for designing AAC systems and configuring interaction techniques. It is an editor for the creation of interaction buttons for the AAC codesign team (occupational therapists, psychologists, assistive technology designers). The editor (see **Fig. 1**) allows to define several features of an interactive button : the morphology of the button (form, size, colour, background, etc.); the representation of the button (image, text and/or sound); the layout and the structure tree of the interface according to topics; the type of feedback (visual and/or sound) and the type of associated function (communication message, running an application; sending messages by means of a text-to-speech synthesis system or sending messages to control domotic connected object in home automation).

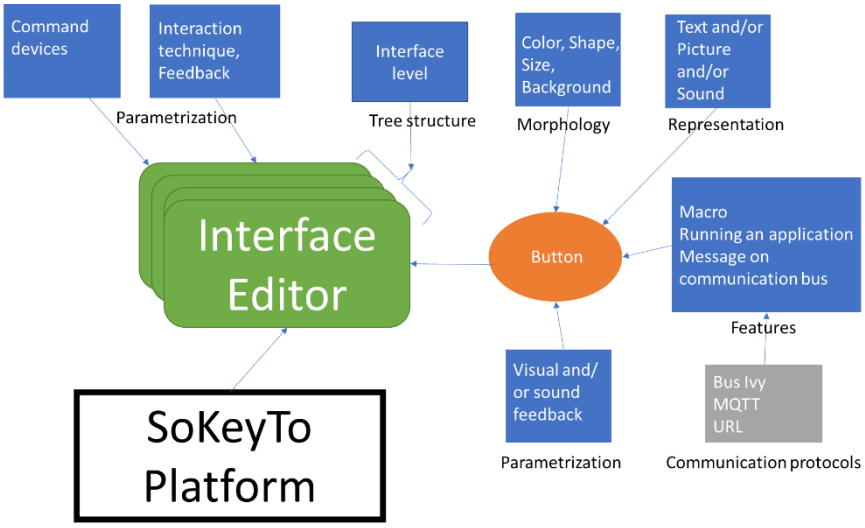


Fig. 1. SoKeyTo functionalities.

The editor also enables to associate to each button the communication protocol required for the button function (for example, the Ivy bus [13] for restoring a voice message, the MQTT network protocol [14]. The editor of the SoKeyTo platform permits to customize not only the AAC interface but also to connect several devices and AAC input interaction modes (scanning system, validation mode, interface return type). Several types of interaction devices (mouse, eyes tracking, joystick, voice recognition, contactor on/off, etc.) are currently supported by the AAC designed with the SoKeyTo platform. The platform also allows setting various validation modes (classic pointing

by pressure or by release, timed click, scrolling system) according to the capacities of disabled people. Many options are possible for these control modes.

All these features allow a fully AAC customized codesign for persons with multiple disabled. We used the SoKeyTo platform for the design of AAC for P1 (see **Fig. 5**).

4 Codesign with the ecosystem

We are implementing the UCD approach of ISO 9241-210 [2] in which we will demonstrate the role of the ecosystem in the UCD activities to design customized AAC. In a previous article, Vella *et al*., [5] reported the observational methods, including the contribution of both clinical scales and ecosystem expertise. The ecosystem has played an important role in both *Understand and specify the context user* activity and *Specify the user requirements* activity (See **Fig. 2**). In this paper, we will describe the role of the ecosystem in the codesign and the adaptation of a customized AAC.

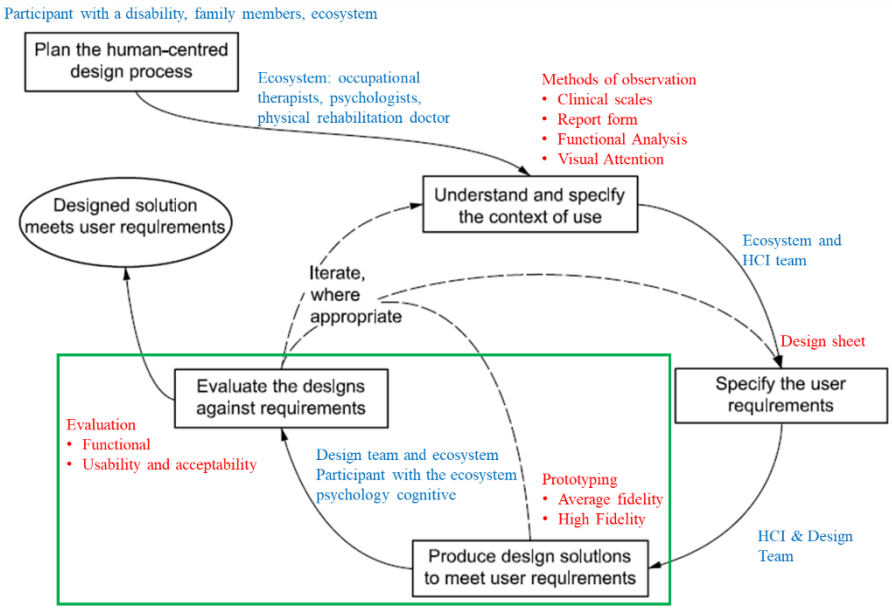


Fig. 2. UCD phases with ecosystem for OUPSCECI design.

The ecosystem and the human-computer interaction (HCI) teams codesigned the AAC interface. The ecosystem has proposed pictogram representations while the HCI team suggested pictogram sizes and contrasts. Both teams have taking into account the perceptive and motor capacities of the person measured by the clinical scales. They also discussed the AAC tree structure to meet user's needs and to be adequate to the intended functions.

This phase has generated many exchanges between the two teams. We codesigned all prototype versions (version 0 for the choice of the most efficient member to control the AAC, version 1 for the place of the control switch (see section 5.3), version 2 for the choice of scanning strategies (see 5.4). The HCI team designed the AAC by means of the SoKeyTo platform while the caregivers specify or clarify new requirements of AAC functions.

The adaptation of AAC to the functional capacities of the person with a disability is characterized by a very long phase of appropriation and adaptation (several sessions per week for several months, reported by the study of Sauzin *et al*. [15]. In this phase, the ecosystem played an essential role during the following phase: parameterization of the control modes (scanning system, timed click, normal click, etc.), ergonomic placement of the AAC in the environment (place of digital tablet and control switch), validation of pictogram representations (size, validation feedback). The involvement of the ecosystem is also important in the learning phase of the pictograms and the navigation mode in the AAC. We discussed each weekly by videoconference, during 9 months, the adaptation of the AAC. This close collaboration resulted in the addition of a release validation mode, the addition of new pictograms corresponding to new needs, the need to study several scanning strategies.

In the following section, we describe the collaboration of the P1's ecosystem and the HCI team in the design and the appropriation of the AAC.

5 Codesign and appropriation of the AAC for P1: a case study

5.1 P1 profile

P1 is an adult person with cerebral palsy, without written and oral expression. P1 uses a foot control device, with five switches, to control his electric wheelchair (see **Fig. 3**). He has athetotic movements in his upper limbs but there are fewer of them at foot level. The only voluntary movements that P1 can control are those of the left foot (better managed on the left (in average 40 times per minute) than on the right (30 times per minute).

The aim is to define the same control device usable by P1 to control his electric wheelchair and his communication notebook. According to Sugawara et al [16] "The strong correlation found between abandonment levels and the simultaneous use of multiple devices should be taken into account by health professionals when prescribing assistive products and providing guidance to users".

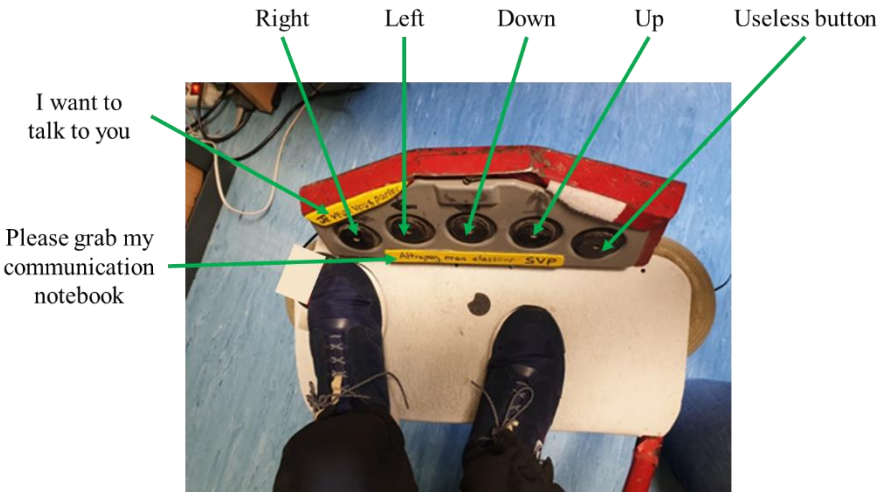


Fig. 3. Foot control of P1's wheelchair. The four grey buttons are used to control the wheelchair and the two yellow markers for "I want to talk to you" and "Please grab my communication notebook".

5.2 Design of a customized communication notebook

The main P1's needs is that his paper's communication notebook should be integrated into the digital interface. This one will also integrate a home automation part (music management, television control) and some others functionalities (access to his calendar, meteo, etc.) identified by his ecosystem (professional and familial caregivers) [5]. We codesigned two previous version used to measure the acceptance and the use according the cognitive, attentional and motor abilities of P1. The main and described in details in [5].

The main difference between version 1 and 2 (see **Fig. 5**) of the communication book is the enhancement of the topics and the tree structure in level in a given topic. The codesign team has structured the interface in three blocks. We chose this layout to allow the user to identify more easily the intention of his/her interaction with the interface. So, we defined the set of pictograms to be categorized: 1) navigation inside a set of a topic; 2) navigation inside the pictogram set of communication or automation home; 3) navigation inside the interface or mention of an error. To improve interaction, we chose to put the pictogram "I was mistaken", accessible at all levels of the interface. (see **Fig. 5**)

The communication interface consists of the following components (See **Fig. 4**). Level 2 offers pictograms to contextualize communication with a caregiver. For example, if P1 wishes to express a problem with his pants. P1 selects the "I have a problem" button, and then the Category interface appears automatically. P1 can then choose the button "clothes" which makes a set of clothes (Level 3) appear, including the pants that P1 can select (Level 4). This contextualization of the level 1 buttons allows: 1) the interlocutor to contextualize the communication and 2) to reduce the production time

of the message by P1. The current interface has 23 contextualization buttons which allows P1 to have a good communication register with his professional caregivers.

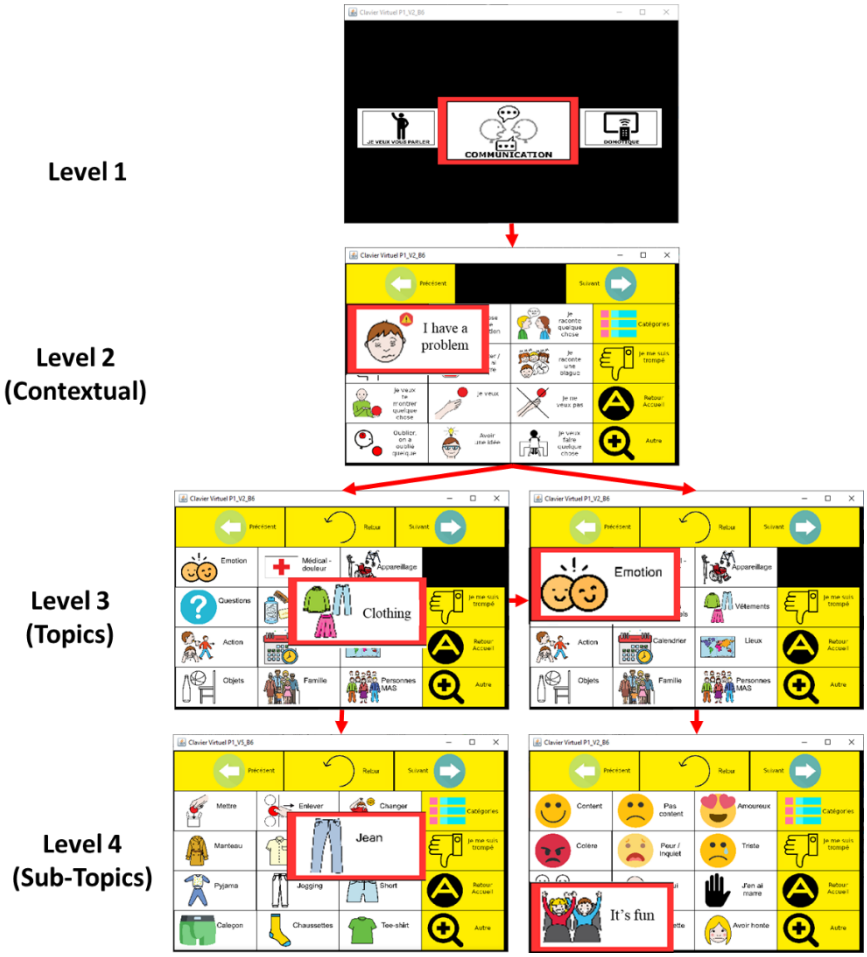


Fig. 4. The different levels of the interface.

The interface (see **Fig. 5**) displayed currently consists of three blocks:

- 1st line (in yellow), navigation pictograms (Previous button: return to the previous interface; Next button: move to the following interface; these two buttons allow to navigate in the set of the same pictogram topic;
- - 4th column (in yellow), Topics button: choice of the communication theme; pictogram signifying a choice error; return to the first level;
- - The central block composed of 4 lines / 3 columns is made up of communication pictograms. The codesign team has added a textual description to facilitate the communication between P1 and her caregivers (family and professional).

The codesign team has moved the navigation pictograms to the first block to optimize the access (saving time) to the navigation buttons. In the V0 version, these navigation buttons were located at the bottom of the interface and P1 needed to scan the whole communication block [5].

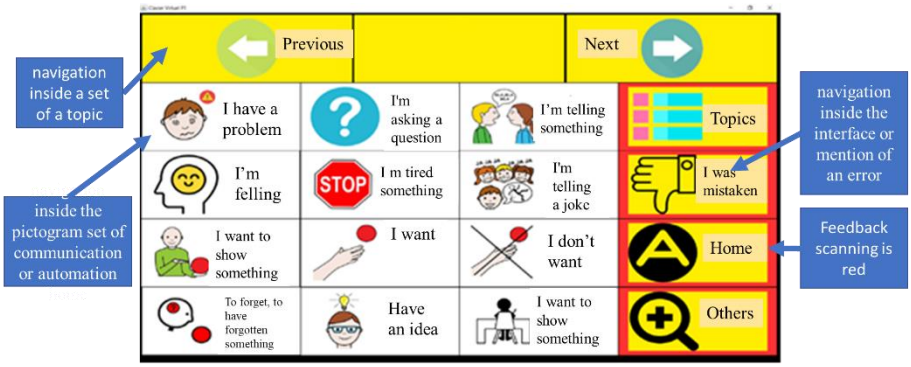


Fig. 5. Communication interface (version 1), level 2.

Ongoing weekly trial carried out by the occupational therapist show that the representation of the interface is suitable even if the number of items is greater than initially envisaged by the ECP (Polyhandicap Cognitive Skills Rating Scale) [17]; scale (from 9 to 12 for the central block). The codesign team has designed this size of the central block because P1 has shown cognitive capabilities under development.

A red feedback (primary color suggested by ComVor scale [18]) mentions the pictogram block or the current pictogram that P1 can select. It is also possible to activate the audio description by means of a text-to-speech of the pictogram selected.

5.3 Device interaction

The ecosystem has carried out a series of tests for the selection of the switch position and validation mode. Real-world trials will be required to define whether pressure or release is used as a validation technique to select a pictogram. Indeed, the muscles involved in each movement (pressure or release) are not the same, so each action does not mobilize the same muscles:

- Validation by release essentially involves the levator muscles of the foot;
- Validation by support requires the mobilization of several muscles and more coordination.

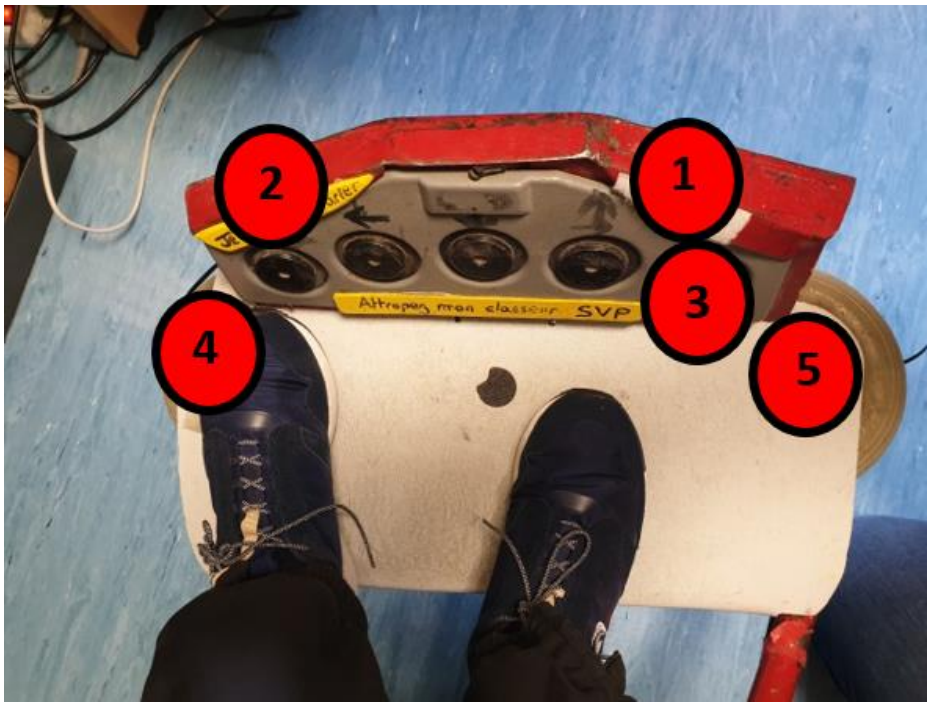


Fig. 6. Various switch positions to control the AAC interface.

In order to evaluate the position of the switch and the selection, occupational therapists positioned the switch button in 5 different places (see **Fig. 6**). The test consisted of finding the best position and the best way to perform the validation action by either releasing or pressing the device. To do this, P1 carried out successive presses and releases on the switch under the control of the occupational therapist. It is to be noted that position 5 was not evaluated because P1 was unable to use the switch in this position. We did not perform release testing at switch place 3. This position makes it difficult for P1 to leave the foot on the switch at this location due to parasitic movements. During the exercises, the person made unintentional or too late selections in positions 1, 2 and 3 but also with the foot sliding on the switch for position 2. On position 4, no parasitic and tiring movements were observed. A complementary test was carried out to verify that this position 4 does not limit the driving of the wheelchair.

In addition, the following results show that position 4 is the most optimized. Indeed, **Fig. 7** shows the average selection time with the foot to perform the action on the switch, i.e., pressing or releasing. We can see that in position 4, P1 takes the least time to perform the action. Similarly than for position 4, P1 makes many selections per minute (see **Fig. 8**). These results are even better for the release.

The occupational therapist performed this trial phase alone in several sessions. This highlights the very important role of the occupational therapist in selecting the appropriate AAC switch based on P1's motor skills.

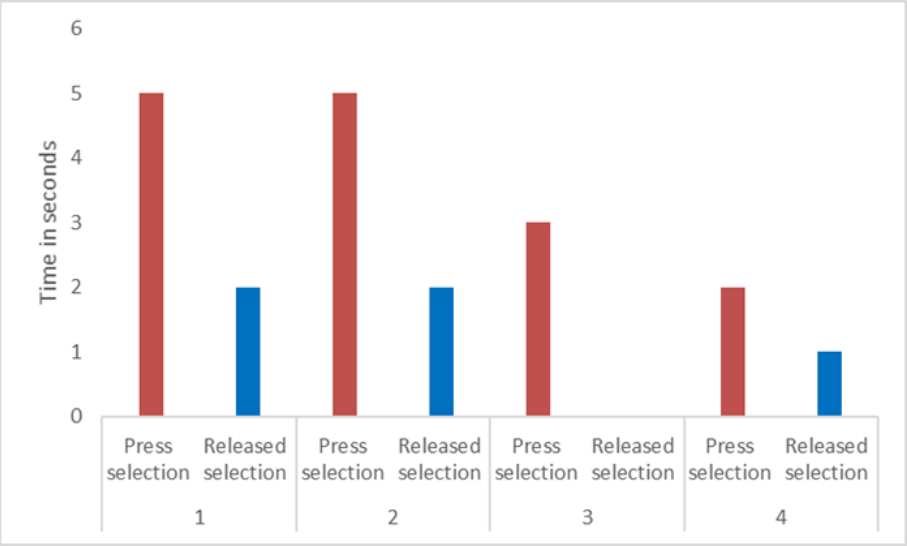


Fig. 7. Mean selection time (including foot movement and selection action).

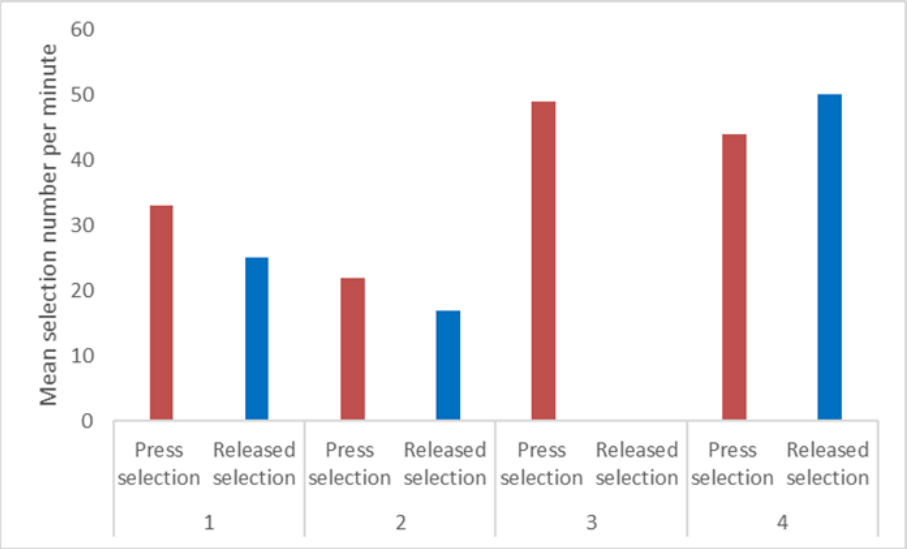


Fig. 8. Mean selection number per minute.

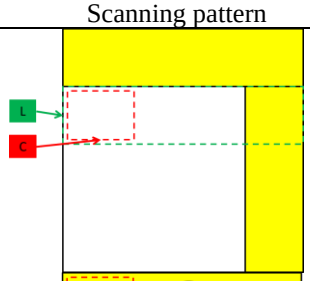
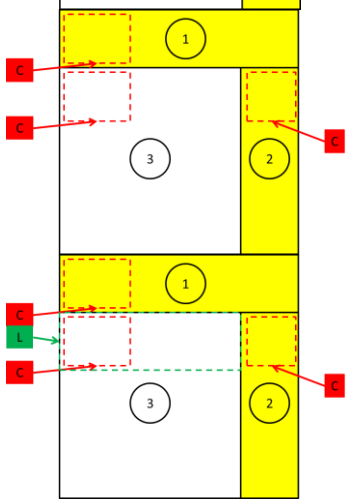
5.4 Scanning strategies

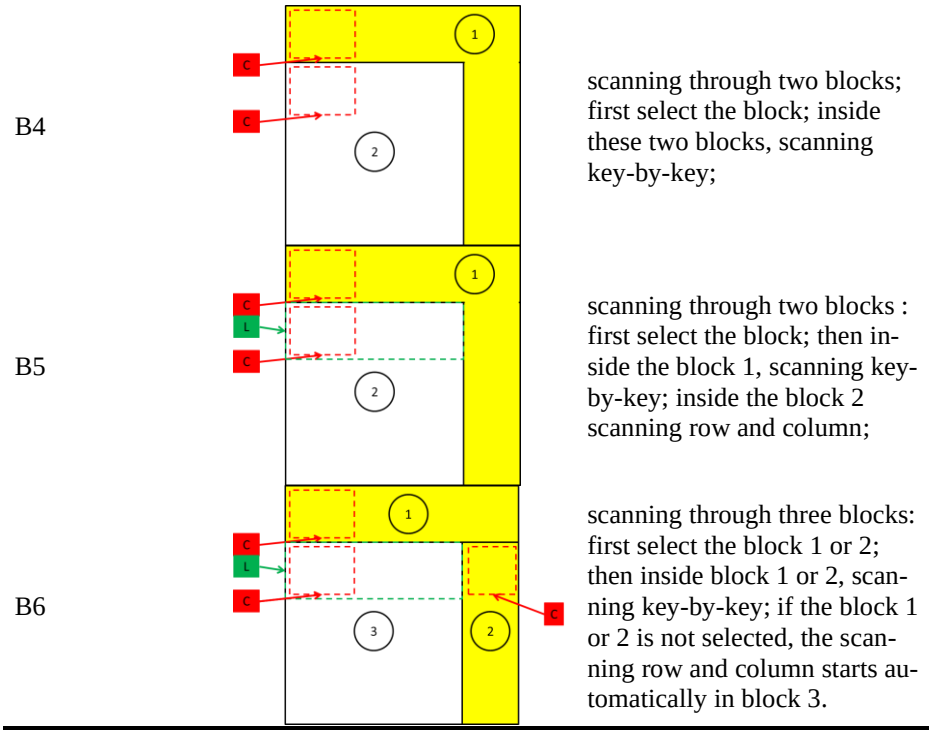
For P1, the only way to communicate and to control his environment will be with a controlled scanning system operated by a single switch (see above, its place). The main problem with these systems is that the communication process tends to be exceedingly

slow, since the system must scan through the available choices. The choice of the type of scanning and the scanning delay are two important parameters, strongly dependent on the motor and attentional capacities of the person with a disability. Several scanning techniques (row/column, circular, group-item and directed scanning, etc.) have been experimented in the field of AAC [19], [20]. Ghedira *et al*. [21] have proposed a method to optimize the scanning delay. White *et al*. [19] reported "*Better accuracy with directed scanning appears to come at the cost of a slower response time. Whereas group-item scanning may be faster, it results in a decreased number of accurate responses*".

In this context, the interface structure (see **Fig. 5**) of P1 led us to study the accuracy and efficiency of six scanning systems. These take into account the global layout of the interface (in 2 or 3 blocks) and the topology of the blocks (one row, 3 rows / 4 columns, one column). The B1 reference scanning is the classical line/column scanning without taking into account the interface structure. The **Table 1** describes the six types of scanning codesigned. In a first time, we estimated the time and the number of clicks to reach the "I tell a joke" button and the "Topics" button (see **Fig. 5**).

Table 1. Scanning type description

Scanning number	Scanning pattern	Scanning description
B1		one block : scanning row and then column;
B2		scanning through three blocks; first select the block, then inside a given block, scanning key-by-key;
B3		scanning through three blocks; first select the block; then inside the block 1 or block 2, scanning key-by-key; inside the block 3 scanning row and then column;



scanning through two blocks; first select the block; inside these two blocks, scanning key-by-key;

scanning through two blocks : first select the block; then inside the block 1, scanning key-by-key; inside the block 2 scanning row and column;

scanning through three blocks: first select the block 1 or 2; then inside block 1 or 2, scanning key-by-key; if the block 1 or 2 is not selected, the scanning row and column starts automatically in block 3.

The figure (Fig 9) shows the number of actions and the minimum time to access the two communication buttons. If we compare these two parameters, the B1 and B6 scans obtain the best performances.

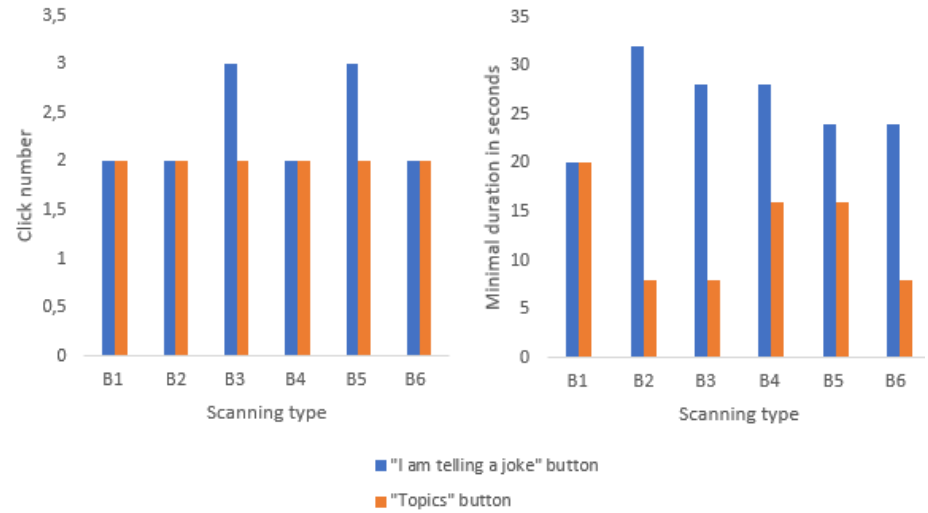


Fig. 9. Theoretical results.

Firstly, P1's occupational therapist in conjunction with the human-computer interaction team has assessed these six scanning strategies. **Fig. 10** shows the position of the left foot at the beginning of each trial. The scanning delay is 4 s. The duration computation starts when the scanning is on the first block of the interface (**Fig. 5**).

Fig. 10. Positioning of the contactor and the left foot.

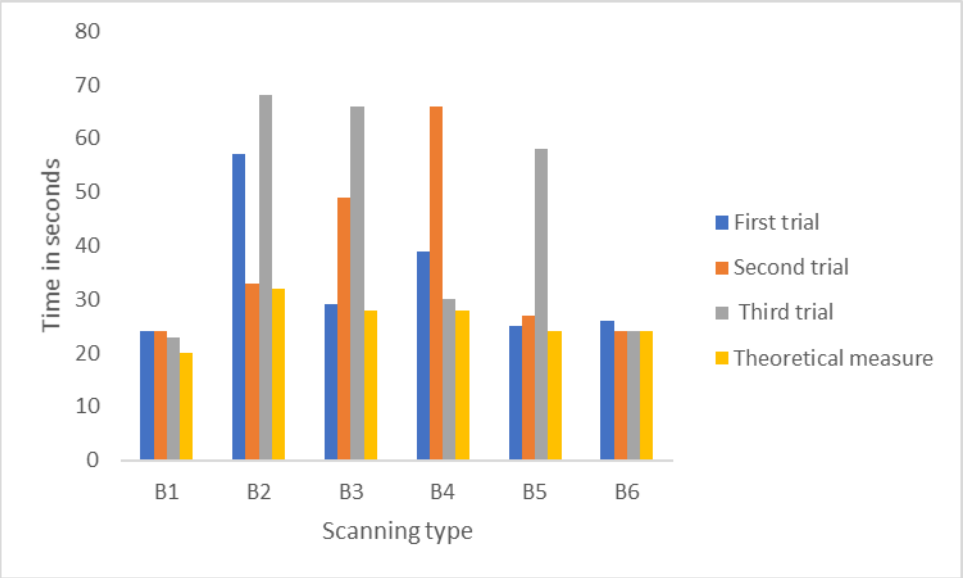


Fig. 11. Effective and theoretical access time to the pictogram "I am telling a joke" for a scanning speed of 4 s.

In all trials, the B1 and B6 scanning get the best performance and there are no interaction errors. The performance of P1 is very close to the minimum time for scanning strategies B1 and B6. On the other hand, in scanning B2 and B3 (2 Delayed selection), B4 (1 No selection) and B5 (Unintended release), interaction errors occurred. The occupational therapist observed unintentional movements from right foot and arm during the tests of B1, B2 and B3 that may disturb the motor control of his left foot.

We have selected the B1 and B6 scanning and we have carried out a new study of the performance measures by carrying out tests to select a pictogram at various levels of the interface tree structure. The hypothesis was to see if the performances of pictogram selection were similar at different levels of the tree structure of the interface communication block. (**Fig. 11**).

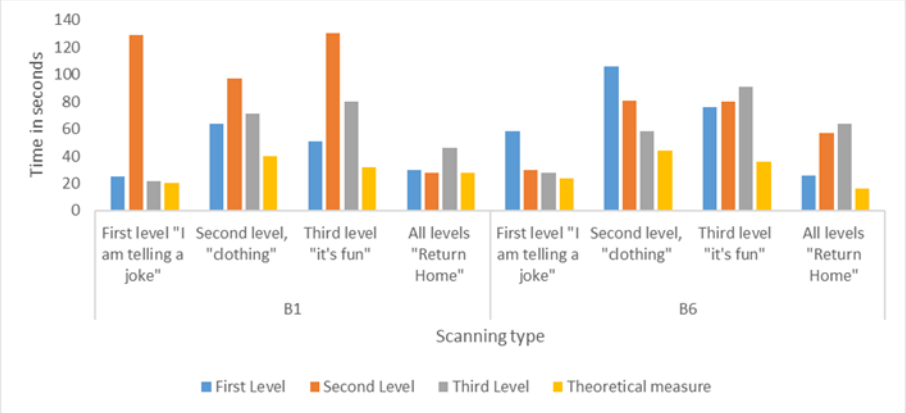


Fig. 12. Effective and theoretical access time to various levels for a scanning delay of 4 s.

The above results (see **Fig. 12**) show a slightly faster average selection time (62.9 s) with the B6 scanning compared to 64.41 s for B1 for all three-test conditions together. On the other hand, P1 achieves 5 click delays and 2 click anticipation with B6 compared to 4 click delays with B1. Selection errors are mainly due to difficulties in controlling foot movement. Occupational therapy sessions show that P1 always needs time to control himself in order to limit unintentional movements.

However, the feeling of P1 is that he prefers B6 scanning which allows a faster return to the home page and previous page (when there is no interaction error) and a faster management of selection errors in the communication block. The appropriation of the interface follows with the B6 scanning.

5.5 Discussion

The tests carried out for the place of the switch, the selection mode as well as on the various scanning demonstrate the key role of the occupational therapist in our codesign process. It also highlights the need for close collaboration between the occupational therapy and AAC design teams in the search for an integrated solution that is accessible

and accepted by the person with multiple disabilities. This close collaboration resulted in the development of an interface structure and a series of scanning systems to be proposed. After this important codesign and testing phase, the observations of the design and customization choices are very encouraging. Indeed, P1 begins to gain autonomy in the use of her interface by taking the initiative in communication. For instance, P1 has interrogated his occupational therapist, "How is she feeling?”.

5.6 Integration of the interface into the wheelchair environment

An important element of the whole setup is the holding system for the tablet fixed on the wheelchair (see **Fig. 13**). This system must be, at the same time, easy to install and to remove by the stakeholders, sufficiently adjustable to allow an ideal positioning of the screen without obstructing the vision of the participant and safe for him and his entourage if there is a shock when he is moving. We have tested several solutions (see **Table 2**) to determine the best balance between ergonomic, practical and safety aspects. The table below presents a summary of the envisaged solutions already tested or under test and for each device their pros and cons.

Fig. 13. Integration of the interface in the wheelchair environment.

Table 2. Solutions tested.

SETUP	PROS	CONS	STATUS
Manfrotto magic Arm (Articulated arm with centre lever to lock all 3 movements) [22]	When tightened, the arm is strong and stable Can be adjusted using a single lever. The positioning of the screen can be precisely adjusted	When the lever is release, the whole arm goes limp, including the ball joints at each end. The rigidity of the arm could be dangerous in case of impact with a wall or a person It is difficult for stakeholders to adjust or remove the device without risking dropping the tablet on the participant	Tested
Rigid tube [23]	Easy to install and to remove Strong and stable	The rigidity of the tube could be dangerous in case of impact with a wall or a person The positioning of the screen can't be precisely adjusted	Tested
Semi rigid arm [24]	Easy to install and to remove Easy to adjust The positioning of the screen can be precisely adjusted Can absorb a shock and reduce the risk of injury	The screen is less stable than with rigid setups and may wobble a little bit when the participant is moving	In test
Flexible arm [25]	Easy to install and to remove Easy to adjust The positioning of the screen can be precisely adjusted Can absorb a shock	The screen wobble a lot when the participant is moving Too much flexibility in the arm could be dangerous in case of impact with a wall or a person Screen positioning needs to be adjusted frequently	Tested

The semi-rigid configuration, which is currently in test, seems to be the best solution to hold the tablet. This solution is easy to use and configure by the stakeholders, highly configurable and sufficiently secure and stable.

6 Discussion on the methodology

Improving understanding of user preferences, the salience of technologies for the user, and personally meaningful outcomes of AT use can contribute to technological solutions that are need-person-centred. For this, we have set up a codesign method. Usually, codesign is performed with end-users. Several adaptations of the codesign tools have been proposed: for instance Gibson *et al*. [12] suggested to take into account the knowledge of "experts" on disabilities; Hendricks *et al*. [11] described research on dedicated methodological approach for involving people living with impairments in codesign projects.

Our approach is different; we have set up a codesign method but with the ecosystem of the disabled person. We have considered members of the ecosystem not only as experts but also as "co-users" of the device (interlocutor customization, use the AAC as a rehabilitation tool). In our case study, the ecosystem involved is composed of a psychologist and an occupational therapist. In Vella *et al*. [5], we demonstrated the pivotal role of caregivers in the clinical evaluation of the motor and communication skills of disabled person. In this paper, we focused on the activity of codesign and evaluation/appropriation of the components of the communication system (communication interface, control modes, ergonomics of the solution in the person's wheelchair environment).

In our approach, it is difficult to measure the contribution of the ecosystem with a reference situation (without the contribution of the ecosystem). We therefore interviewed the HCI team about the configuration proposals that they would have suggested as modalities of interaction without the exchanges with the occupational therapist. The designer team would have proposed the scanning strategy (row/column) B1 and the mode of selection by press. However, the results respectively reported in sections 5.3 (Device interaction) and 5.4 (Scanning strategies) show that these configurations do not achieve the best usability rates. As reported by Fedirici *et al.* [26] "*Abandonment may be due to assignment of inappropriate devices or failure to meet user needs and expectations*". Thus, the ecosystem is the best guarantee that the needs and the best possible configuration of P1's AAC were taken into account.

This study also highlights the impact of associating rehabilitation treatment and assistive technology designer and of following up on users for short- and long-term use. The study also demonstrates the importance of considering the need for reusing assistive products for the environmental

One challenge in this approach is the balancing viewpoint of the ecosystem and the HCI team. As reported by Hendriks *et al*. [11] equivalence amongst the ecosystem and the HCI team is very important. The various meetings (conducted mainly by videoconference due to the COVID pandemic) have led to the structure of the interface in three blocks, to the proposition of a set of scanning strategies. The ecosystem proposed the

set of pictograms (knowledge of the need for communication) while the researchers proposed pictogram sizes, contrasts based on knowledge of accessibility.

The two teams agreed on the importance of supporting collaboration and finding a shared language.

However, this approach, however, raises the time needed to learn and customize the AAC for P1. The whole customization process is very long (more than six months at the rate of one session per week) and requires a very significant involvement of occupational therapists.

7 Conclusion

We described our codesign approach with the ecosystem of a person with multiple disabilities to design his adapted AAC. This is an interesting approach to involve those who will be directly or indirectly affected by the design. However, it raises ethical issues, to the extent that the needs of people with disabilities are respected. Our approach demonstrates the strong interest of collaborating with the ecosystem, on the one hand in the codesign activity but also in the customization and learning phases of the AAC. Indeed, this case study and the results we obtained show us the interest of our approach to design adapted systems. It also show us the interest of undertaking a longitudinal study with more participants. The aim of this future study would be to validate our approach by evaluating the usability and long-term acceptability of the device by the participants and their ecosystems. It could also allow us to assess the contribution of these codesignated devices to improve autonomy, well being and social interactions of the participants.

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