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Simplified modelling based on an ontology of users with cerebral palsy interacting with people or systems: case study of an assistive system used in mobility

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Abstract. Cerebral palsy is a domain not trivial when one should developed interactive systems. Based on that, an ontology describing different elements of cerebral palsy disability is proposed in order to support designers of interactive applications dedicated to users with this profile. This paper presents the iterative process used for the creation of this ontology, developed using Protégé software. The results of an initial evaluation based on a questionnaire are explained. A proof of concept for communication aid software usable in mobility illustrates its use by designers. Various perspectives arising from this ongoing research are then listed.

Keywords: Cerebral palsy, User model, Ontology, Communication aid, Mobility, Protégé, ComMob, Disability.

1 Introduction

The World Health Organization (WHO) has classified the various types of disability into different categories [2]. We argue that, it is important for designers of interactive systems to at least be aware of the characteristics of users with disabilities who are likely to use the systems in question, and then to develop their knowledge on this subject.

This paper focuses on the category of physical disability, and more specifically on athetoid cerebral palsy (CP) [5]. This disability is often due to a lack of oxygen either during pregnancy, during delivery or a few hours after delivery [37]. This lack of oxygen can be caused by cardiac arrest or placement of the umbilical cord around the neck. There are two categories of cerebral palsy disability: athetoid and spastic. The athetoid category causes involuntary movements of the upper and lower limbs [43]. These movements are amplified during moments of stress, and disappear during sleep. The spastic category is symbolised by stiffness in the upper and lower limbs [4].

In addition, people with CP have varying degrees of difficulty in speaking; this is known as dysarthria [9]. This speech problem causes a distortion of the sounds coming out of the person's mouth, but the person usually has no problem formulating correct sentences. It is important to note that people with athetoid CP often do not have intellectual or cognitive disabilities.

To compensate for speech difficulties, there are various communication aids [19]. The best known is the virtual keyboard. It is present on all computer devices. The virtual keyboard comes in several categories, meeting different needs [29]. Then one can find pictograms either in physical form in a communication notebook, or in computerised form in a communication aid application [13]. In both cases, the pictograms are organised into categories and themes. Finally, there are physical communication aids. This category includes the finger guide, the unicorn, eye tracking and voice recognition [12].

Designers (or more generally engineering specialists) are often unaware of such information. Therefore, modelling can be very useful to support the development of interactive applications for people with cerebral palsy. To do this, we used an ontology. In computing, an ontology is a structured set of themes and concepts representing a field of information [42]. The ontology constitutes a data model representing a set of concepts in a domain, as well as the relationships between these concepts. It is used to reason about the objects in the domain concerned. An ontology makes it possible to organise and structure a body of shared knowledge and to establish a common vocabulary.

In this paper, we explain the approach taken to arrive at the first version of an ontology for modelling various elements related to the athetosis-type PC disability, without seeking to be exhaustive. The aim of this ontology is to help designers gain a better understanding of this disability, and consequently to help make their applications accessible to them.

This user modelling contributes to a traditional stage in the design of interactive systems in human-computer interaction [10] [25] [28]. This stage contributes to the identification of the user's needs in relation to the interactive system in question. The starting point for all modelling is the collection of data, which can come from a variety of sources (field observations, study of the literature, knowledge extraction from experts in the field, etc.). Next comes the structuring of this data. Finally, the modelling stage can begin.

This paper is organised as follows. Section 2 presents a brief state of the art in user modelling. Section 3 proposes a simplified ontology, focusing on cerebral palsy disability. Based on this proposal, Section 4 provides the results of an initial evaluation of the ontology. Section 5 describes a proof of concept of the use of this ontology using a communication assistive application. The paper ends with a conclusion and research prospects.

2 State of the art in user modelling

User modelling supports the design of interactive products and software, and user interfaces [10] [39]. It can be considered as one of the pillars of the field of human-com-

puter interaction. Generally speaking, it enables us to understand end users, while helping to identify their characteristics, needs, behaviours and/or preferences, etc., in order to create solutions that are tailored to them.

The objectives of user modelling can in fact be varied [40], but can also be combined:

- Understanding users - User modelling aims to gain a more or less in-depth understanding of end users, their characteristics, skills, objectives and motivations. A better understanding can also be used to train designers. This is the objective of this paper.
- User-centred design [27] - By placing users at the centre of the design process and analysing them in detail, user modelling can help create products and services that effectively meet their needs and expectations.
- Optimising the User eXperience (UX) - By analysing user behaviour and preferences, user modelling helps to improve the user experience, by improving the quality of human-machine interactions.
- Personalisation and adaptation - By developing user models, it is possible to personalise interactions according to individual preferences, context of use and/or past behaviour, for example. This is part of the vast field of intelligent interaction.

Upstream of user modeling, there are various methods that can be combined [30] [35], for instance:

- User research - this includes qualitative methods (interviews, observations, focus groups, brainstorming) and quantitative methods (questionnaires, usage analyses) to gather information about users and their needs.
- Personas and scenarios - The creation of personas [7] [26] and usage scenarios (both textual and diagram-based, e.g. using UML activity diagrams) makes it possible to represent different types (or profiles) of current or future users and their possible interactions with the system.
- Cognitive modelling - this involves analysing the mental processes involved in using the system, including perception, attention, memory and decision-making. Frameworks on this subject have existed for many years, see for example the decision ladder proposed in [36].
- Analysis of usage (or interaction) traces - this involves exploiting real usage data (e.g. website usage) to understand user behaviour and identify areas for improvement (e.g. by noticing human errors and/or that pages are being ignored by users).
- It is also possible to identify and formalise a set of characteristics that will serve as criteria for customising or adapting both the user interface and the recommendations to be provided.

A user model is a data structure that is used to capture certain characteristics of an individual user, and a user profile is the actual representation in a given user model [40]. For example, an entity-association model, a class diagram or an ontology can be used. The data structure used in our research is the ontological structure (see Section 3), following on from our previous work [16]. The data included in the model depends on the purpose of the application. The model can include personal information such as

users' names and ages, job types, interests, skills and knowledge, goals and plans, likes and dislikes, or data about their behaviour and interactions with the system [38].

In the case of people with disabilities, it can be difficult to identify certain needs or characteristics (for instance interaction skills) that need to be reflected in the user model, particularly in the case of communication disorders. Various case studies can be found in the literature. For example, in [21] and [23], the authors highlight the contribution of members of the disabled person's social environment in human-centered approaches. In [1], proposals are made for adapting needs capture methods. In [8], the authors show how difficult it is to capture the needs of users who are deprived of speech, in the context of designing an eye-tracking system for computer control. Many other examples of studies can be found, such as [24] or [41].

3 Towards ontological modelling for cerebral palsy disability: approach and first version

3.1 Objectives

The aim of our work on ontological modelling of cerebral palsy disability is to produce an initial version that presents, in simplified form, elements to support the training of interactive system designers. The aim is to identify a set of characteristics that can help them in their work, by giving them initial ideas about these potential target users.

Such support for this initial familiarisation is only proposed as a preliminary training stage. In the context of real projects, it will of course be essential for the designers who have been made aware to then interact directly with the target users, if possible throughout a user-centred design process [27].

3.2 Work process

Two Master's level designers in computer science were involved in the process. As part of their training, they had taken several teaching modules in software engineering and human-computer interaction, and had already had the opportunity to work on projects and/or training periods involving the design of interactive systems. Their objective was to propose an ontology focusing on cerebral palsy, aimed at designers of interactive systems intended for users with this profile. The aim was to raise designers' awareness of essential (representative) characteristics to be taken into account in projects.

Figure 1 summarizes the work process.

These designers began by reading various scientific papers on cerebral palsy in general, as well as papers describing work on designing systems for people with cerebral palsy (for example [16], [17], [18] ou [20]). It was also possible to consult web sites dealing with disability in general, and cerebral palsy in particular (including [11]).

Throughout the project, they were able to interact with two experts in the field of designing and evaluating systems for users with disabilities. These systems concerned users with disabilities directly (Parkinson's disease [34], cerebral palsy [17], intellectual disability [14]) or indirectly (disability awareness in companies [32]). It is important to

note that one of these two experts is a person with cerebral palsy, and has a deep understanding of the needs and characteristics of the field. Interaction with the experts took the form of weekly meetings, and e-mail exchanges for additional information, particularly on cerebral palsy disability and the modeling of features related to it. During the meetings, the experts were able to study the ontology under construction and provide advice on how to improve it. The experts were also consulted on the procedures to be used to evaluate the ontology (importance of a pre-evaluation, versions of the questionnaire, types of participants, data analysis).

Several versions of the ontology have been produced, as illustrated in Figure 1, all of which have been presented and evaluated at meetings, with the aim of improving the ontology.

The various versions of the ontology were produced using the Protégé software [33]. Protégé is an ontology editor. It is an open source knowledge management system. It was created at Stanford University by Marc Musen. It is very popular in the semantic web field and in computer science research.

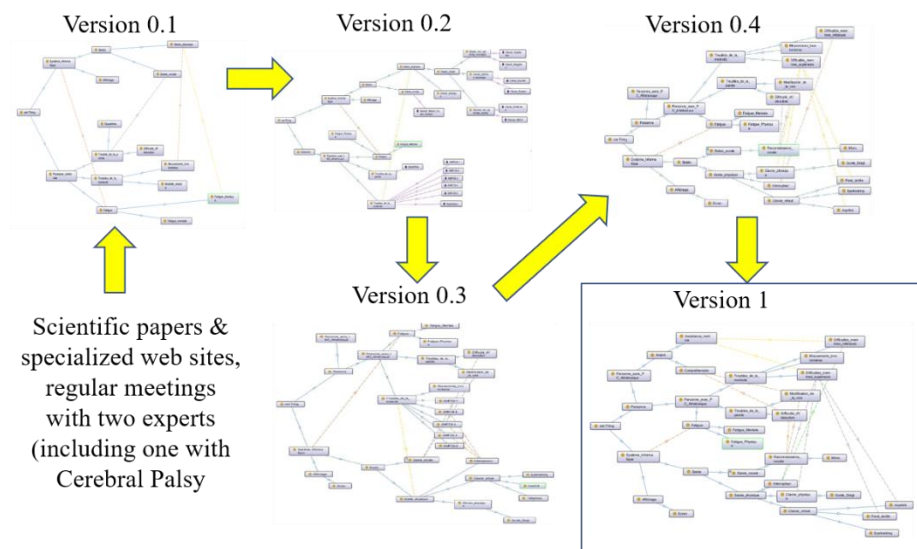


Fig. 1. Global approach

Figure 1 is not intended to show and explain each version of the ontology. Its aim is merely to give an overview of the various stages (versions) involved in arriving at the final version of our ontology. It is essentially this final version (called Version 1) that is explained in this paper (see Section 3.3, Figure 2).

The first version (Version 0.1) only used the class and link functionalities (as defined by Protégé). Very general, it was considered too incomplete to be useful for a developer's understanding of cerebral palsy disability. This version did not cover enough aspects and lacked nuance about the different profiles of people with cerebral palsy. Indeed, it is important to specify that individual differences (which can be significant)

exist and that each individual has their own preferences and abilities. It was also proposed to establish several models for several situations, and to add documentation via the annotation system of the Protégé software. In addition, the class names were not explicit enough to be clearly understood.

In the second version (Version 0.2), the designers decided to use individuals (in the sense of Protégé). Individuals are classes that can be instantiated only once. However, during the development of the ontology, the use of individuals quickly showed its limitations, as in order to model the cerebral palsy disability, they realised that the number of individuals would be too large, and therefore that the ontology would be incomprehensible. In addition, the terms used were too scientific and, as a result, application designers might have difficulty understanding the ontology. For example, the terms based on the acronym GMFCS (Gross Motor Function Classification System) designate different levels of limb mobility but are not explicit enough. In addition, the decision to develop the different types of virtual keyboard in this version was too specific and could not take into account all the existing virtual keyboards. This second version did not show how individuals interact with each other, or how people with disabilities interact with the system. Finally, it was also relevant to add clarifications regarding existing laws on certain classes. For example, specifying that the display is via a screen and that Fitts' law [31] must be taken into account. This law specifies that the larger the target to be reached on a screen, the easier it will be to reach it.

In the third version (Version 0.3), the designers decided to return to using classes for the ontology in order to make it more comprehensible. However, even when documented, the class names were still too precise. The decision was taken at a meeting to generalise the themes, using words that everyone could understand.

The third version was pre-evaluated on the basis of a questionnaire (the questionnaire used is described in Section 4.1) with a limited number of evaluators (6 evaluators). The initial comments (see Section 4.2) collected with the questionnaire were used to improve the ontology (in a fourth version, called Version 0.4) by simplifying the scientific themes and overly general concepts.

A final version (called Version 1) was then produced. It is described in the following section.

3.3 Description of the latest version of the ontology (Version 1)

For the latest version of the ontology (Figure 2), a person without cerebral palsy has been added. This person is part of the social environment of the person with a disability, also called the ecosystem by [22] [23]. We have chosen to mention only the caregivers because they are the ones who will have an impact on the behaviour and use of the system by the person with cerebral palsy.

This final version is the result of the combination of all the meetings and discussions. In particular, the experts provided a range of explanations on disability and its main characteristics, on the various technical means of compensating for disability in human-machine interaction, and on the importance of interaction between the disabled person and their caregiver(s). This final version takes also into account the feedback from the pre-evaluation carried out with 6 evaluators, see Section 3.2. This ontology is made up

of two parts. The first represents the disabled person and the able-bodied person; the characteristics of these people and their interactions are summarised. The second part lists the different systems that enable people with cerebral palsy to communicate.

An overall description of this ontology, visible in Figure 2, is as follows. The ontology, in its current simplified version, aims to express that we consider two types of people: those with cerebral palsy and those without cerebral palsy. The person with cerebral palsy may be characterised by motor disorders, speech disorders, as well as fatigue, which may be mental or physical. Speech problems can lead to elocution difficulties and a change in voice. Motor disorders can lead to difficulties with the lower limbs, as well as the upper limbs, and involuntary movements. The person without cerebral palsy may be a caregiver, able to provide assistance with motor skills; this person may have problems understanding the person with cerebral palsy.

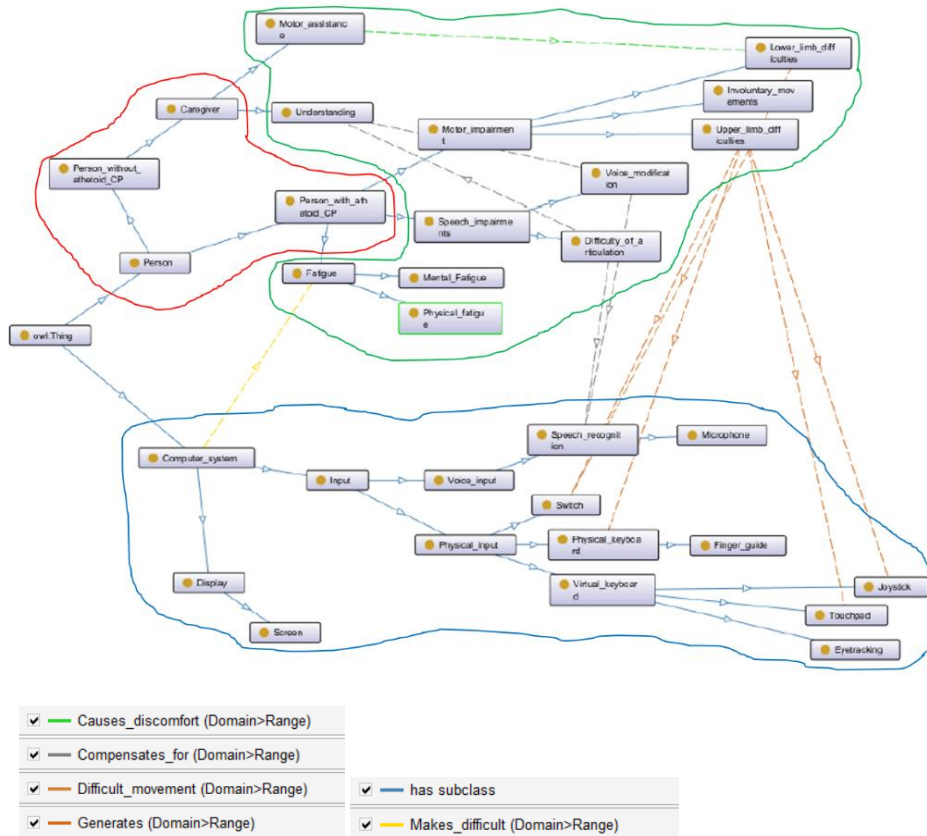


Fig. 2 Latest version of the ontology, obtained at the end of the process (called Version 1). The zone highlighted in blue corresponds to the field of IT and assistive technology; the red zone considers people; the green zone is specific to the field of disability.

The ontology also considers a computer system with a screen-type display. Using the system can cause fatigue. Input can be vocal, with voice recognition, requiring a

microphone. Input can also be physical, with a switch, a physical keyboard (which may require a finger guide) or a virtual keyboard. The virtual keyboard can be combined with a joystick, touchpad or eyetracking.

Blue arrows correspond to subclasses (classical is-a relation in ontology). Green, gray and orange arrows represent relationship between concepts expressing possibilities of compensation (for instance by using *speech_recognition*).

The definition of each ontology theme is provided below.

Person: Represents a person.

Person_without_athetoid_CP: Represents a person without athetosis cerebral palsy.

Caregiver: Entity representing a person without cerebral palsy providing assistance to the person with cerebral palsy.

Motor assistance: Entity representing any motor-related assistance that can be provided (movement in space, limb guidance, etc.).

Understanding: Entity representing the caregiver's ability to understand when interacting with a person with cerebral palsy.

Person_with_Athetoid_CP: Represents a person with athetoid cerebral palsy.

Motor_Impairment: Entity grouping together the various motor disorders linked to athetoid cerebral palsy.

Involuntary_movements: Involuntary movements of the limbs of a person with athetoid cerebral palsy. These movements are more or less important depending on the person.

Upper_limbs_difficulties: Includes all the difficulties linked to the motor skills of the upper limbs, for example slight, partial or total paralysis of the upper limbs.

Lower_limb_difficulties: These include all difficulties related to lower-limb motor skills, for example the use of a cane to get around, or a manual or electric wheelchair.

Speech_Impairments: This entity covers the various speech disorders associated with athetoid cerebral palsy.

Voice_modification: Also known as dysarthria, this entity represents a change in voice tone and articulation linked to athetoid cerebral palsy.

Difficulty_of_articulation: This entity represents speech difficulties linked to athetoid cerebral palsy, more specifically the symptoms of athetosis on language, i.e. uncontrolled and involuntary movements of the tongue muscle.

Fatigue: Entity grouping together the different types of fatigue experienced by people with athetoid cerebral palsy.

Physical_fatigue: Fatigue felt physically by the person.

Mental_fatigue: Fatigue felt mentally by the person.

Computer_system: Represents any computer system.

Display: Entity representing the types of display of the computer system

Screen: Display screen of a computer system. Note that it is often preferable for the user to have a large enough screen to make it easier to use the computer system, particularly when using a virtual keyboard.

Input: Entity grouping together the different types of information input, whatever their nature.

Voice_input: Entity covering the different types of voice input.

Voice_recognition: Type of voice input. Entity grouping together the different voice recognition tools.

Microphone: Tool used for voice recognition.

Physical_input: Entity grouping together the different types of physical entry.

Physical_keyboard: Type of physical input. Entity grouping together the different physical keyboards.

Finger_guide: Type of equipment linked to the classic keyboard. This is a piece of equipment or a keyboard equipped so that the user cannot press two keys at the same time or change trajectory. It generally consists of a plastic plate with holes for each key placed on the keyboard.

Virtual_keyboard: Type of physical input, generally displayed on a screen. Entity grouping together the various tools for using a virtual keyboard.

Touch_pad: Tactile tool for using a virtual keyboard.

Joystick: Equipment connected to the computer system enabling a cursor and/or virtual keyboard to be used.

Eye_tracking: Input method for a virtual keyboard. Using a camera, it follows the user's eye in order to direct a cursor and/or use a virtual keyboard.

Switch: Type of physical input. Switches can be placed on an appliance or in a house in the case of a home automation system. They require movement of the user's upper limbs, and may also require movement of the lower limbs.

4 Initial evaluation of the ontology, based on a questionnaire

4.1 Questionnaire adapted from the System Usability Scale (SUS)

To evaluate the ontology, we used a questionnaire adapted from the System Usability Scale (SUS) [6]. This questionnaire consists of 10 questions, scored from 0 to 4, ranging from "Strongly disagree" to "Strongly agree" (using a Likert scale). Each question alternates between positive and negative wording. A SUS score above 70 is considered, according to some studies, to be a favourable score [3].

In the initial SUS questionnaire (translated in french), we replaced the word 'system' with 'model'. The questions are as follows:

1. I think that I would like to use this model frequently
2. I found this model unnecessarily complex
3. I think the model is easy to use
4. I think I would need the support of a technical person to be able to use this model
5. I found the various functions in this model were well integrated
6. I thought there was too much inconsistency in this model
7. I would imagine that most people would learn to use this model very quickly
8. I found this model very cumbersome to use
9. I feel very confident using the model
10. I needed to learn a lot of things before I could get going with this model

Using these 10 questions, combined with a free-response question, we were able to evaluate and identify aspects of the ontology that needed to be adjusted.

The questionnaires were administered using Google Forms, an online platform for creating questionnaires and analysing responses.

4.2 Results

Initially, a small-scale evaluation of version 0.3 of the model was undertaken with the aim of refining our latest modifications and taking a step back, as well as allowing an evaluation of the questionnaire itself. On a panel of 6 users (average age 23; 5 men and 1 woman, field of activity: 5 in IT and 1 in health), the average score attributed to our ontology was 54.58. Feedback from users focused mainly on two points:

- The visibility of the arrows, which were considered difficult to discern.
- Clarification of certain terms, in particular the meaning of the finger guide.
- This analysis also highlighted a lack of clarity in the question "I think that I would like to use this model frequently". In fact, users did not take into account the context of the development of systems dedicated to people with cerebral palsy. In order to clarify this point, a contextual information was provided.

Following the application of these adjustments to the ontology and questionnaire, a larger-scale evaluation was carried out, this time on Version 1 of the model. From a sample of 23 participants (average age 31; 12 men and 11 women), the average score obtained was 70.80. The breakdown of the evaluators' field of study or activity is as follows: the majority study or work in the IT field (12 participants). For the others, the fields are: healthcare (2), engineering (other than IT) (2), human sciences / teaching (3), management (3), not mentioned (1).

The diagram visible in Figure 3 illustrates the normalized average scores for each question. Normalization was achieved by considering the two types (odd/even) of questions (items) in the S.U.S. questionnaire and the method used to calculate the score of an item (for odd items: subtract one from the user response; for even-numbered items: subtract the user responses from 5). The average for each question (from 0 to 4) was then divided by four to obtain a value between 0 and 1.

Two questions received the lowest averages: Question 1 ("I think that I would like to use this model frequently"), and Question 4 ("I think I would need the support of a technical person to be able to use this model"). These averages show that the context would have benefited from even greater clarification. The average SUS score for these 23 participants was 70.54 (from 100, that can be considered as *good*).

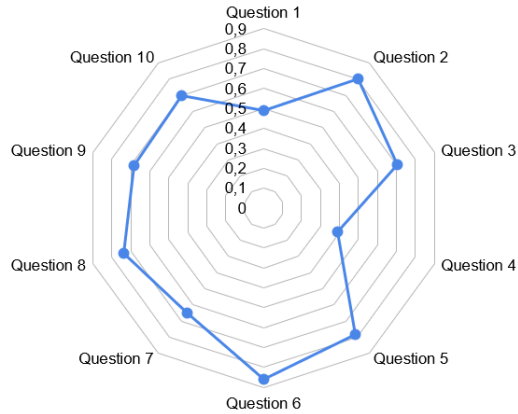


Figure 3. Normalized scores of each question for all the answers

Restricting ourselves to the responses of people working in the fields of IT and health, the score stands at 68.03, slightly below a value considered favorable, but generally consistent with the overall score. We still notice a low average for Question 1. However, the drop in value for Question 4 is no longer apparent (see Figure 4).

The evaluation of the model gives promising first results. It also gave us the opportunity to identify areas for improvement by studying the verbatims provided by the participants.

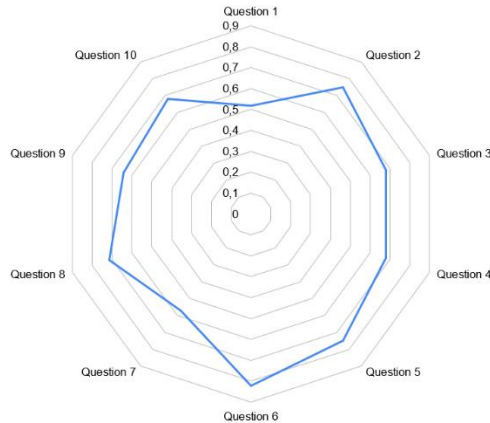


Figure 4. Normalized scores for each question for people in IT and healthcare domains

In the following section, a proof of concept gives an illustration of the exploitation of the elements of the ontology. The framework used is that of a communication assistive system for people with cerebral palsy, usable in mobility.

5 Proof of concept on using the ontology for the development of a communication assistive system usable in mobility

This section describes through a proof of concept the design of *ComMob Web* based on the proposed ontology. *ComMob Web* is an application whose first version (called *ComMob*) was proposed and developed by the first author of this paper, during his PhD [17]. The aim of this assistive system is to help people with motor disabilities and speech problems to communicate in mobile situations. One profile targeted in particular concerns people with athetoid cerebral palsy.

ComMob stands for Communication and Mobility. Initially in software form, it was transformed into a web application for easier access. *ComMob Web* offers the user a set of pictograms grouped by theme and category. All the user has to do is select them to formulate sentences. Users can prepare dialogues in advance to make discussions more fluid. Finally, pictograms, categories and themes can be managed (added, deleted...). Figure 6 shows examples of *ComMob Web* screen pages (in french). For more information, see [15].



Figure 6. (1) ComMob Web homepage. (2) Sentence formulation page with pictograms. (3) Dialogue preparation page. (4) Topic deletion page.

From now on, let us imagine that *ComMob Web* has not yet been developed, and that our objective is to develop a communication assistive system for people with cerebral palsy. Let us assume that the client has provided us with the ontology presented in this paper to understand initial elements relating to cerebral palsy.

By studying the ontology, we can see that we have information on the people who will be using our future application, i.e. the disabled person and their caregiver. Then, we have explanations of the cerebral palsy disability. Finally, we can see a list of IT tools that can be used by the disabled person.

This ontology enables us to better understand certain needs and constraints of target users. For example, the fact that people easily experience mental fatigue tells us that

we need to make the application as easy to use as possible. The use of icons to represent dialogues makes it easier to orientate oneself than would be the case with full texts. Another way of reducing the mental workload is to integrate a system that detects your surroundings and automatically suggests appropriate dialogues. To better understand this, let us take the following example: if the user is in an airport, the application could suggest prepared airport-related dialogues.

The ontology also points out that it is not easy for certain people with cerebral palsy to be precise in their movements. For this reason, the buttons used to interact with the application need to be large.

We also note that not all users have the same configuration (phone, tablet, with keyboard, voice recognition, etc.). This can encourage us to create a tool that can respond to as many cases as possible. That is why ComMob has been exported to the web, to be as compatible as possible. Of course, we have to make the tool responsive and ensure that it works on multiple devices and with all major web browsers.

The fact that caregivers are present in the ontology is also valuable for us. Indeed, they are important actors in the lives of the target users, and it is essential to take them into account. That is why, for example, an alert button can be integrated into the system to broadcast aloud the fact that you are in difficulty, to draw the attention of those around you. It may also be useful to allow you to notify a relative or help center via SMS or e-mail that you need assistance.

In this way, this ontology can help us to think about, and better understand to a certain extent, the needs and expectations of target users.

However, we have identified a number of areas where the ontology could be improved. It would be possible to have more detail on how a disabled user interacts with a smartphone, tablet and computer. It would have been useful to have concrete examples of communication situations with a caregiver, as well as with different actors in the outside world. Finally, it would have been desirable to have specific recommendations for user interface design. Further research perspectives are listed in the next section.

6 Conclusion

In this paper, we proposed a first version of an ontology related to the cerebral palsy disability. This version will evolve following the evaluation carried out and then following other uses and evaluations to be implemented. The approach was followed by two junior designers in regular interaction with two experts in the field of human-machine interaction applied to disabilities, including one with cerebral palsy (integrated into a team participating in numerous projects linked to disability domain). The aim of this ontology was to offer a simplified representation of different elements linked to cerebral palsy. This representation aimed to be easily understandable by designers of interactive applications so that they can adapt their analysis to this type of disability. Our ontology allows us to provide a first level of knowledge (before going deeper into it).

Several versions of this ontology were produced before arriving at a final version (called Version 1). Subsequently, we evaluated this version of the ontology with a panel of people who did not necessarily have knowledge in the IT field or in the field of disability. This evaluation was done through an online questionnaire and then the data was analyzed. Overall, the results are promising, with the ontology being generally understandable by the participants.

From this first version of the ontology, several research perspectives can be highlighted. First of all, it would be possible to improve this version by (1) continuing to test it with people without specific knowledge concerning cerebral palsy, then (2) by testing it with several cerebral palsy disability specialists, and also with caregivers. In addition, we can also ask for additional opinions from people who have cerebral palsy themselves to make improvements or additions. These complementary evaluations could be done in the form of a questionnaire as we did for the evaluation of this version and/or during interviews. Note that other ontology evaluation methods may be considered following a state of the art on ontology evaluation in general. To find specialists and people with cerebral palsy, it would be possible to contact specialized centers welcoming people with disabilities. The ideal would be to go on site to ensure that the assessments or interviews go smoothly.

Following the new data collected, a new version of the ontology could be produced and again evaluated with another panel of people in order to further improve this ontology (approach to be repeated if necessary).

In Section 5, a proof of concept was presented by using a concerned a communication assistive system, usable in mobility, called *ComMob Web*. This approach aimed to give an example of designing an application based on the first version of the ontology. It would be interesting if it were used in the case of other projects targeting different systems aimed at the users targeted in this paper.

A longer-term perspective would be to transpose this ontology to other disabilities, using the same approach. Finally, the creation of a general ontology which could be valid for a wide spectrum of disabilities would be very interesting to allow designers to adapt their product more easily.

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