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### ► To cite this version:

Nadine Vigouroux, Eric Campo, Frédéric Vella, Loïc Caroux, Mathilde Sacher, et al.. Multimodal observation method of digital accessibility for elderly people. *Innovation and Research in BioMedical engineering*, 2021, 42 (3), pp.135-145. 10.1016/j.irbm.2020.03.002 . halshs-02553707

**HAL Id: halshs-02553707**

**<https://shs.hal.science/halshs-02553707v1>**

Submitted on 28 Aug 2023

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# Multimodal observation method of digital accessibility for elderly people

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Reçu le ...; Reçu sous la forme révisée le ...; Accepté le ...

Disponible sur Internet le ...

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## Abstract

This article presents a new methodological framework for multimodal observation of digital technologies. It is based on the use of mixed methods developed in the interdisciplinary MAN project founded by CNRS. It focuses on the digital accessibility of older people. The originality of the method lies in the implementation of a method combining qualitative and quantitative measurement to determine relevant indicators. These indicators characterize the person's behavior when using a technology and its usability. We show how these indicators are built, based on the cross-referencing of data. We present the different tools (questionnaire, interviews and technological data recording tools) used in the MAN method in a living laboratory environment controlled with four volunteers. Two use scenarios are proposed to illustrate the method in assessing the accessibility of a tactile application for older people without a digital divide and without disabilities. We present the recorded qualitative and quantitative data and illustrate by an example the unrelatedness of these data through a specific annotation tool.

**Keywords:** Observation methods, mixed methods, accessibility, seniors, autonomy

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## 1. Introduction

Digital technology is gradually invading our daily lives. It induces profound changes in our society, in our ways of living and communicating. Digital technologies are reinventing alternative ways of living and all sectors of the economy: transport, leisure, culture, information processing, security, medical practices... Digital technology is revolutionizing the way we produce and interact with our environment. However, the use of digital technology raises challenges for older people. Older generations often have difficulty using technologies compared to their younger counterparts, particularly in terms of usability and accessibility [1]. Between 2015 and 2050, the number of people aged 60 and over will increase from 900 million to 2 billion (from 12% to 22% of the world population<sup>1</sup>). In France, one in three French people is over 50 years old and there is a clear increase in the population over 80 years old, which will be accompanied by a twofold increase in the number of dependent elderly people by 2060 [2].

This ageing is leading to the rapid emergence of products and services for this elderly population<sup>2</sup> in the fields of health, safety and autonomy, housing, services, leisure, communication and assistance systems [3]. The scope of the research work to be carried out is clear: 1) to design systems adapted to the needs of frail elderly people (> 80 years of age), who are very often in a digital divide with normal or pathological disorders of ageing to guarantee their autonomy and a good quality of life; 2) to study the accessibility and/or usability of these systems [4].

The ISO 9241-210:2010 method (clause 2.15) [5] aims to evaluate the quality of the user experience, UX (User eXperience) as "a person's perceptions and reactions that result from the actual and/or anticipated use of a product, system or service". Although UX is recognized as a central element in product design and evaluation, [6] clearly mentions the advantages of a combination of UX evaluation methods. Similarly, [7] suggests that the disciplines of Human Computer Interaction and Usability

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<sup>1</sup> <https://www.who.int/features/factfiles/ageing/fr/>

<sup>2</sup> <https://www.economie.gouv.fr/entreprises/silver-economie-definition>

Engineering collaborate to make technology more accessible, useful and nice for older people. The work of [8] has shown that it is difficult to take into account the heterogeneity of older people as well as new situations in the use of mobile devices and touch screens.

Although some usability [9], [10] and accessibility studies provide important recommendations for interface design, the work of [6] and [7] suggests the implementation of multidimensional observations. The purpose of these multidimensional observations is to provide recommendations for developing solutions that meet the needs and functional capacities of people with disabilities within the meaning of the International Classification of Functioning, Disability and Health<sup>3</sup>.

The objective of this paper is to briefly recall the motivations for the mixed methods, the context and the observation method of the MAN project (Cross Evaluation Method for Digital Accessibility) [11]. We will then describe the types of qualitative and quantitative data collected for illustrative purposes on a participant. Then we justify our choice of mixed methods which we illustrate through the conceptualization of six indicators defined in the MAN project. Finally, we illustrate our conceptual annotation model of videos as indexing tools for calculating indicators.

## 2. Motivations of Mixed Methods in the field of Autonomy

Many observation methods have been developed in order to understand and explain complex situations in the use of technologies by the elderly [12]. Traditionally, there are three types of methods: quantitative (numerical data), qualitative (direct observation, interview, video, etc.) and mixed methods (MM) which ideally include the advantages of the other two methods. Mixed methods have been widely used in the human and social sciences (sociology, educational sciences, health, etc.). Methodological approach is defined as mixed when it combines quantitative and qualitative methods in the same study [13]. In his classification, J.W. Creswell [14] proposed four models: triangulation, complementarity design, explanatory design and exploratory design. Mixed methods can also be classified according to three dimensions: the temporality (simultaneous or sequential), the weighting of one or other of the tools used (equivalent status or dominant status) and the data combination procedure (merger, integration and connection). We refer to [15] for a detailed description of these dimensions. J.W. Creswell [16] also proposed five essential features of mixed methods: (1) the collection and analysis of both quantitative and qualitative data, (2) the use of rigorous procedures in quantitative and qualitative research, (3) the integration (or combination) of the results of qualitative and quantitative studies, (4) the design of mixed methods through the development of procedures in which this data collection, analysis and integration take place, (5) the use of a theory (and philosophy) related to these procedures.

J.W. Creswell [14] has also shown that working only with quantitative methods or qualitative methods no longer corresponds to the main approaches used in the social sciences and humanities. Nevertheless, mixed methods are still little used: a quantitative and qualitative analysis of 481 articles presented in the conference proceedings of the International Association of Strategic Management shows that the use of mixed methods remains limited and that the potential of mixed methods compared with unique methods is not fully exploited [15]. For example, disability studies are based on the social model of disability and refer to a universal design to think of an environment accessible to all using mainly exploratory and quantitative methods [17]: *“Les méthodes sont conçues de telle sorte qu'elles incluent les expériences personnelles et les points de vue des personnes handicapées dans la formulation des questions et de la conception de la recherche, dans l'interprétation ainsi que le compte rendu des résultats. Les méthodes employées peuvent comprendre des observations ethnographiques, des « histoires orales », l'analyse de récits ou de discours, des focus groups, des entretiens non directifs, une analyse des productions artistiques et littéraires »*. Similarly, apart from certain publications, Bujold et al., [18] on the use of MM in social sciences and health sciences, the French-language literature presenting the general framework of this conceptualization remains modest. Created in 2007, the Journal of Mixed Research Methods aims to create links between researchers of mixed methods and to be a platform for debate and discussion on important issues of research in mixed methods. We postulate that observing the uses of digital technologies also requires the implementation of MM. Based on this observation, it is this approach to mixed methods that we wanted to implement in the context of the MAN project described below.

## 3. Context: The MAN Project

The MAN project was developed as part of an interdisciplinary AUTON<sup>5</sup> challenge by the French National Research Centre in 2016. It brings together a national consortium of laboratories from technical sciences and human and social sciences fields. Its

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<sup>3</sup>[https://apps.who.int/iris/bitstream/handle/10665/42418/9242545422\\_fre.pdf;jsessionid=AB3438862F9A1A40AF0B6DE49245C0EF?sequence=1](https://apps.who.int/iris/bitstream/handle/10665/42418/9242545422_fre.pdf;jsessionid=AB3438862F9A1A40AF0B6DE49245C0EF?sequence=1)

<sup>4</sup> "The methods are designed in such a way that they include the personal experiences and perspectives of persons with disabilities in the formulation of research questions and design, in the interpretation and reporting of results, and the methods employed may include ethnographic observations, oral histories "Analysis of narratives or speeches, focus groups, non-directive interviews, an analysis of artistic and literary productions".

<sup>5</sup> Défi Auton: <https://www.cnrs.fr/mi/spip.php?article1407>

objective is to develop and design a mixed method of multidimensional evaluation on digital accessibility for older people with sensory or cognitive disabilities with or without a digital divide [19]. This collective approach has been discussed by some authors such as [7] who have shown that it is essential to have multidisciplinary, digital (questionnaires, traces) and socio-anthropological observation tools [20], and measures to evaluate the proposed solutions with a use-oriented methodological approach [21], and, in a second step, to validate them. The importance of the acceptability and usability of technological solutions for older people was also highlighted [11]. This multidimensional approach has been proposed for other observation and monitoring situations and considered essential as a success factor [22]. The MAN project was built on a real need for information collection and analysis methods that combine mixed "qualitative and quantitative" methods that are strongly encouraged in the digital field for autonomy [7], [23]. Indeed, the complementary coupling of these data is essential to understand the different interaction mechanisms and the adequacy of the proposed solutions with the users' needs and their profile [11]. Quantitative data provide experimentally observable and quantifiable elements of the person's true behavior in a use case while qualitative data provide empirical information on the profile, motivation, barriers and other representations of digital technologies [24]. A set of quantitative and qualitative methods is proposed in the technical report ISO/TR 16982 [10] showing the richness of the tools available today and the rigor with which these methods must be crossed. Today, digital measurement tools (activity monitoring [21], physiological measurements [25], and posture analysis [26]) can complete the range of these tools mentioned in [5].

The assessment of the conditions in which people are, faced with the accessibility of a technological tool, is not a compilation of different approaches but their combination, which requires a real cross-elaboration process. The idea is to ultimately provide an appropriate response to the accessibility of digital applications (access to information, controls over one's living environment, access to medical data, etc.) on a touch pad, computer, interactive television or smartphone. It seems important to us to adopt a collective and iterative evaluation at different stages of the experimentation process (having the feeling of a pre- and post-experimentation technology can have a meaning on people's clichés about the technology but also about the awareness needed for people with a digital divide). This assessment can also be functional if it is based on questionnaires, validated clinical scales and semi-structured interviews.

#### **4. MAN observation methodology**

The MAN observation method has been designed in a transdisciplinary way [19]. It must make it possible, by cross-referencing the data, to explain, for example, motor behavior with movement analysis data and knowledge of the person's health profile or technical correction of the disorder (cane, orthopedic shoe, glasses, hearing aid, etc.). It can also be used to analyze the intention with eye movements, posture, vocal exchanges or knowledge of the anxiety state. In a cross-methodological approach, defining the purposes of the evaluation is also a real challenge. It must refer to concrete situations that are easily observable and verifiable by an observer, whether or not the observer is the individual being observed.

The tools of the MAN method [11] were chosen to understand the person's behavior in situations of device use and digital application. They are based on ISO 9241-210 (utility, usability, satisfaction level) [5] and ISO/TR 16982 [10] for quantitative and qualitative methods but also on behavioral measurement instruments (attitude, motor and attention). They are composed of qualitative analysis tools (observation and two pre- and post-experimental interviews) and quantitative analysis tools (technology acceptability questionnaire adapted by [27] itself based on the AttrakDiff questionnaire [28], questionnaire on the socio-cultural, technological, health and technology use profile, data from motion sensors [26], eye movements [29], activity logs, ambient sensors [30] and video and audio records. The reader may refer to [11] for a detailed description of the tools. The questionnaires, semi-structured interviews and observation grid were developed in an iterative and incremental way, taking into account the partners' experiences and the analysis of the implementation of an experience with an elderly person. This method should make it possible to analyze the six multimodal indicators (social relationship of the participant; motivation of the participants in the use of technologies; appropriation effect induced by experience; behaviors and psycho-social attitudes; usability and utility) defined by the consortium [11]. Complex work is underway on the specification, combination (fusion, integration and connection) and weighting of these variables derived from the quantitative and qualitative data that define the indicators. This is a study in its own right that meets the concerns of some researchers on the definition of a relevant methodological framework for the analysis and interpretation of multimodal data [31], [32] or those of researchers using mixed methods [14], [15] and [16].

#### **5. MAN experiment**

The implementation of this observation method in a semi-controlled situation seems to us fundamental to immerse the person in realistic cases of use. This simulation took place in the Maison Intelligente de Blagnac (MIB) Living Lab [33]. This one reproduces the living environment close to a conventional habitat with the advantage of being adapted for experiments and observations to be carried out. Four participants were recruited, all with no digital divide and no cognitive impairments detected. They were respectively 68, 87, 89 and 90 years old. The three oldest participants were more particularly relevant to the target population of the study. The recruitment of a younger participant was a control participant. The control participant daily uses the tablet, smartphone or computer. The three older participants use the tablet or computer.

All participants were first informed of the objectives and course of the study through an information notice, an informed consent form and an image right. The study was submitted and approved by the Research Ethics Committee of the Federal University of Toulouse (n°2018-103). No participant was able to see the experimental set-up before the day of the experiment and none of them were paid for their participation in the study. Below, the InTacSMAN application, scenarios and methodological tools of the MAN observation method [11] are reminded.

### 5.1. InTacSMAN Application

InTacSMAN is a version of the InTacS application [33] in which the functionalities (home automation and multimedia control of MIB, Internet browser) have been designed to enable the achievement of expected scenarios. The design objective of InIacSMAN was to make it accessible to visually impaired people without a digital divide. The modifications of the interface are described in [35].

### 5.2. Scenarios

Participants had to realise activities in a controlled environment. The MIB was chosen for these activities thanks to its automated environment that allows participants to carry out the activities as they are in their own home. The MIB infrastructure also allows observation of the participant's behaviors on these activities from different recordings (video, audio, activity sensors and activity logs).

In the study, two activities were proposed to participants. Each of these activities consisted in 10 minutes' scenarios; each participant were invited to use the InTacSMAN application (Figure 1) to perform actions within the MIB. Each activity had a specific objective from the methodological point of view.

The objective of the first scenario was the observation of the participant's behavior in the monitored situation. In this first scenario called "Let's Learn to Control the Environment and Communicate!", the participant used the tactile tablet to control the MIB and search for an information on the web in full autonomy by following instructions.



Figure 1: Participant 4 using InTacSMAN for home automation controls in the lounge. The zoom-in frame displays an example of the InTACSMAN application’s interface.

Scenario #2 was a free scenario. The participant had to perform some tasks in its own order: Go take a snack in the kitchen; Look for the opening hours of the town hall of Blagnac; Turn on the TV and say the program in progress; Go to the bathroom to wash the hands; Get the weather prediction for the next 5 days; Find the address and contact information of a hairdresser or look for the addresses of an EHPAD<sup>6</sup>. These tasks were mentioned on paper cards as a reminder. The participant had to say when return information were requested. He was authorized to take notes on a paper or the tablet.

<sup>6</sup> Etablissement d’Hébergement pour Personnes Âgées Dépendantes : Long-term nursing home.

Tab. 1 describes the process and observation tools used during the experiment conducted within the MIB.

Tab. 1. Chronology of the experience and documents used in the implementation of the MAN.

<b>Pre-experiment</b>	
Information letter on the project and the experiment	
Consent letter	
Image rights	
Cognitive profile	
Questionnaire 1 (Socio-professional, lifestyle, use of technology)	
Q2-Pre - Acceptability Questionnaire	
E1 – Interview 1	
<b>Experiment</b>	<b>O b s e r v a t i o n</b>
MIB	
Presentation of the InTacsMAN application by the researcher	
Trial of the InTacSMAN application by the participant	
<b>Experiment: 3 scenarios</b>	
<i>Scenario 1 « Controlled scenario: "Let's learn to control the environment and communicate! "» (Eye tracking+ 360 video + log + heart rate measurement)+ pause</i>	
<i>Scénario 2 « Free scenario: "Activity of daily life when waking up from bed!" » (Eye tracking+ 360 video + log +heart rate measurement)</i>	
<b>Post-experiment</b>	
Q2-Post- Acceptability Questionnaire	
E2 – Interview 2	

### 5.3. Cognitive profile

At the beginning of the study, all participants were administered standard cognitive tests. The Mini Mental State Examination [36] assessed general cognitive functioning. The verbal and spatial span tasks [37] were used to assess short-term verbal and visuo-spatial memory. The letter-number sequencing task [37] and verbal fluency test [38] assessed working memory and executive functioning. This battery of cognitive tests was added after the experimental phase of MAN [35] in order to describe the cognitive abilities of the participants.

### 5.4. Questionnaires, interviews and observations

Two questionnaires were used during the experiment (see Tab. 1). The Q1 questionnaire covered socio-professional aspects, lifestyle habits and use of technology. It was given before experimentation and the participant had to answer the 56 questions presented with or without the help of the experimenter, followed by a semi-directive E1 interview, Pre-experimentation, aimed at assessing knowledge, attitudes and practices regarding information technologies (computer, tablet, smartphone) as well as possible deficiencies that limit the use of technological devices. A second Q2 (Pre-questionnaire) on the acceptability of digital access technologies was submitted again to the participant and the same Q2 (Post-questionnaire) was submitted after the experiment. Finally, a semi-directive E2 interview, Post-experimentation, allowed us to collect any changes in attitudes towards technological devices. An observation grid has been set up to record our observations in real time according to two main categories: factual observations such as performances, repetitions, requests for help, aloud comments, and additional annotations such as emotion identification - facial expressions, gestures other than those related to the task.

### 5.5. Logs of activities

Each participant's action on the tactile tablet was recorded during each scenario. The information (coordinates x, y, t of the tactile pressing, name of the button of the InTacSMAN application) allow to determine the duration of the activity, the number of tactile pressing per sub-activity of the scenario and the precision of the contact point on the tablet.



### 5.6. Audio/video data

The audio and video data were captured through two devices that allow us to have both an objective and subjective view of the experimental scene (Figure 2). Concerning the objective vision (point of view that is not the participant's), we used a Kodak Pixpro SP360 4K camera fixed on the tablet thanks to a special support that we printed in 3D. This camera allows to have a 360° angle around the tablet and also to record the sound. The 360° video also provides information about the environment that can infer the participant's behaviour during the experiment. Concerning the subjective vision (participant's point of view), an "ETG 2w" eye-tracker (developed by the "SMI" company, Germany)<sup>7</sup> was used to collect the eye movement data of the participants in real time (number and average duration of fixations on objects of interest) during each scenario. It has a lightweight portable system that allows collecting eye data without disturbing the participants' motion in the space. The eye-tracker was linked to a "Galaxy Note 4" smartphone that collected the data. The smartphone was located in a little backpack carried by the participant. Data were collected from both eyes with a 60 Hz sample rate. These data were analyzed with the "BeGaze 3.6" software (SMI).

These two devices for capturing audio and video streams allow us to have a complete and synchronized view of all the events that occur in the experimental scene: what the subject looks at, what he says, what he does on the tablet or in the environment, the expressions of the body and face.

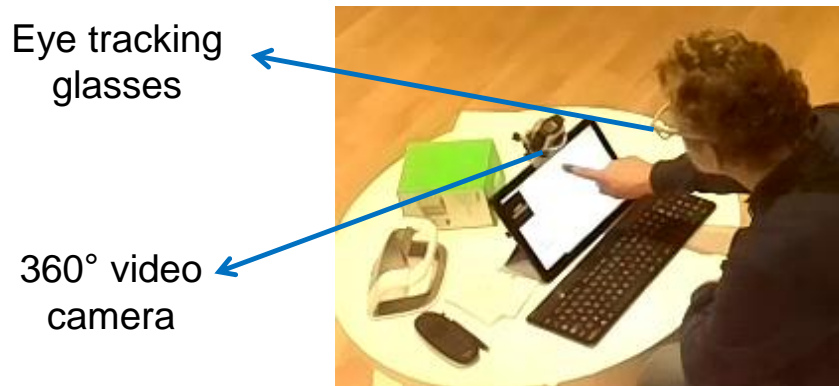


Figure 2: Placement of the camera on the tablet.

### 5.7. Measurement of physical activity and use anxiety through heart rate

It has been shown that heart rate variability (HRV) is a good indicator of a person's emotional regulation because it measures the balance between the sympathetic and parasympathetic nervous system [42]. HRV is derived from the continuous heart rate measurement, more precisely from the R-R intervals of the heart signal. For this we used the Polar Belt H7<sup>8</sup>. This belt is connected to the Actigraph watch, which records all R-R intervals but also estimates the person's physical activity. The amount of physical activity will allow us to correlate HRV also with physical effort. The anxiety phases will be deduced from the HRV signal using the system training on the calibration phase. This calibration phase takes place before the experiment and submits the person to an induced relaxation phase and a stressful phase (calculation or observation games) to identify the reaction of each person's HRV to these controlled situations. The anxiety/stress phases identified from the HRV will be correlated with activity logs and eye data to explain the participant's interactive behaviour.

### 5.8. The synchronization technology solution

As seen above, the experimental platform is composed of various data capture devices (touch pad, eye tracking, heart rate measurement and audio/video recordings). Each device records its data in its own time base, linked to a local clock. In order to be able to fusion these data, we need to synchronize them on a common time base to allow a homogeneous observation in time. However, as it stands, the variability of the recording format and the time drift related to the accuracy of the embedded clock of each device do not allow us to synchronize these data with a satisfactory accuracy for observation. To solve this problem, we have developed a software tool that evaluates the difference between the clock of the computer connected to the capture device and that of the MIB's Network Time Protocol (NTP) server, every 10 seconds. This deviation data makes it possible to correct all the logs in order to have a common time base and, therefore, sufficiently accurate to make a homogeneous observation in time.

<sup>7</sup> [https://www.smivision.com/wp-content/uploads/2017/05/smi\\_prod\\_ETG\\_120Hz\\_asgm.pdf](https://www.smivision.com/wp-content/uploads/2017/05/smi_prod_ETG_120Hz_asgm.pdf)

<sup>8</sup> [https://support.polar.com/e\\_manuals/H7\\_Heart\\_Rate\\_Sensor/Polar\\_H7\\_Heart\\_Rate\\_Sensor\\_accessory\\_manual\\_Francais.pdf](https://support.polar.com/e_manuals/H7_Heart_Rate_Sensor/Polar_H7_Heart_Rate_Sensor_accessory_manual_Francais.pdf)

The audio and video data are also synchronized with the rest of the data through a visual and sound clap triggered by the participant at the beginning of the experimental session.

## 6. First analyzes of qualitative and quantitative data for the control participant

To illustrate, we proposed to transfer the individual contribution of each observation tool of the MAN method to the control participant.

### 6.1. Profile of control participant

The Q1 questionnaire and the pre-experiment interview described the control participant's level of technological expertise. He was a 68-year old retiree, living in a couple in the city centre. He had a Ph.D. and worked in the field of industrial research. He said mastering digital tools. He regularly and autonomously used digital devices (smartphone, computer, and tablet) but did not have assisted living technologies. The frequency of use was more than one hour per day for the phone and the tablet. Uses were mainly devoted to searching information on the Web and messaging service. He did not have medical devices and compensation aids. He said not be afraid of technologies. By contrast, according to him, technologies allow to open access to knowledge.

The battery of cognitive tests was used to describe the cognitive abilities of the control participant. He did not have cognitive impairment at the level of general cognitive functioning (Mini Mental State Examination MMSE >27). Compared to its reference age group, he had correct verbal and visuo-spatial short-term memory capacities (verbal span task: standard score = 19/20; spatial span task: standard score = 13/20). Working memory and executive functioning abilities were also correct (letter-number sequencing task: standard score=12/20; verbal fluency test: lexical fluency score= 28, categorical fluency score =40).

### 6.2. Acceptability questionnaire

Questionnaire's results had shown that participant had a global acceptance of technologies equivalent between before and after the realization of the scenario (global score pre-test = 2.25; global score post-test = 2.31). However, the assessment of pragmatic (pre = 2.33, post = 2.17) and hedonic (pre = 2.50, post = 1.67) qualities decreased, while the assessment of perceived safety (pre = 1.67, post = 2.00) and social influence (pre = 2.00, post = 2.75) increased. The appealingness rating did not change (pre = 2.83, post = 2.83).

### 6.3. Analysis of activity logs

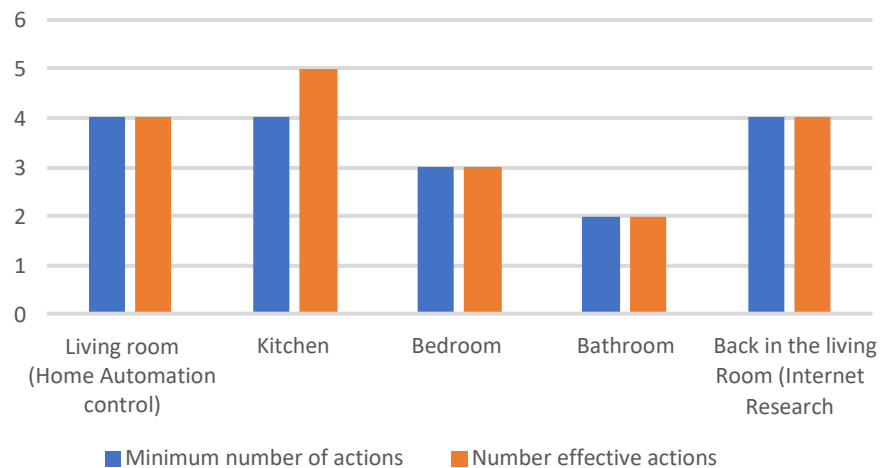


Figure 3: Tactile actions by sub-activity.

The analysis of the activity logs allowed determining the duration of the activities (2mn 91s for the controlled scenario against 5mn 28s for the free scenario). This analysis has given the number of pressing by sub-activity. Figure 3 shows that participant 4 made only one interaction error in the control scenario, which attests to his expertise in the use of new technologies. Determining the duration of each sub-activity requires the annotation of the 360° video with the ELAN annotation software to determine the sub-activities of the scenario (See 7.4).



#### 6.4. Eye movements data

For the controlled scenario, data had shown that the total number of fixations and the average fixation duration were more large on the tablet (number: 191; average duration: 234 ms) than on the instruction sheets (number: 109; average duration: 174 ms) or on the objects of the ambient environment (number: 82; average duration 210 ms).

For the free scenario, data had shown that the total number of fixations and the average fixation duration were more large on the objects of the ambient environment (number: 915; average duration 220.5 ms) than on the tablet (number : 636 ; average duration 202.62 ms) or on the instruction sheets (number : 128 ; average duration 189.09 ms).

#### 6.5. Postural analysis

Several key postures (e. g. sitting on the sofa in front of the touch screen, sitting with the interface on your knees, standing, ...) adopted during the various interactions with the touch interface were studied. The mean angular values of the axial skeleton and upper limbs observed for each posture and the corresponding ergonomic scores, obtained from the Rapid Upper Limb Assessment (RULA) [39] were calculated. Biomechanical and ergonomic analyses revealed that, during interactions with the tablet placed on the coffee table in the living room, the postures adopted were not satisfactory and require a short-term modification. This could be explained in particular by an important head and trunk flexions ( $>20^\circ$ ) and a high load on the right shoulder, which was necessary to move the index finger on the different icons of the interface. For example, the posture adopted during navigation on a web page and in particular the scrolling of the page was particularly constraining from an ergonomic point of view. In addition to a significant flexion of the trunk ( $30^\circ$ ) and the neck ( $15^\circ$ ), this task required a strong involvement of the shoulder in all three planes of space, with a flexion greater than  $60^\circ$  combined with abduction and medial rotation. In the same way, a low elbow flexion ( $<30^\circ$ ) associated with high a forearm pronation ( $>130^\circ$ ) were considered as binding values. All these angular parameters result in a RULA score of 5 [39], indicating that "a study and modifications are needed without delay". For this particular situation, this score of 5 means that the participant's posture (position of the participant during his interaction with the tablet placed on the coffee table) is very constraining from an ergonomic point of view and that it is therefore necessary to avoid being in this posture. It therefore seems necessary to modify the conditions under which the interaction took place in order to make the participant's position less restrictive and therefore less risky in terms of musculoskeletal disorders.

In this same situation, a modification of the posture was noticed when the participant delayed finding information on a page in this uncomfortable posture: he naturally changed his postural strategy by grabbing the tablet and placing it on his lap, thus reducing the RULA score from 5 to 3. Standing postures seem to be the least ergonomically risky positions even if the participant holds an object in his hand, provided that it does not exceed 2kg. Among all the observed postures, the sitting writing position appeared to be the least ergonomically constraining.

#### 6.6. Stress situations analysis

One of the most commonly used parameters for anxiety/stress estimation is the low high frequency ratio LF/HF from HRV [40] which indicates the relationship between the sympathetic and parasympathetic system. Figure 4 shows this LF/HF ratio over the entire duration of the experiment. Each positive variation in the ratio indicates stressful situations.

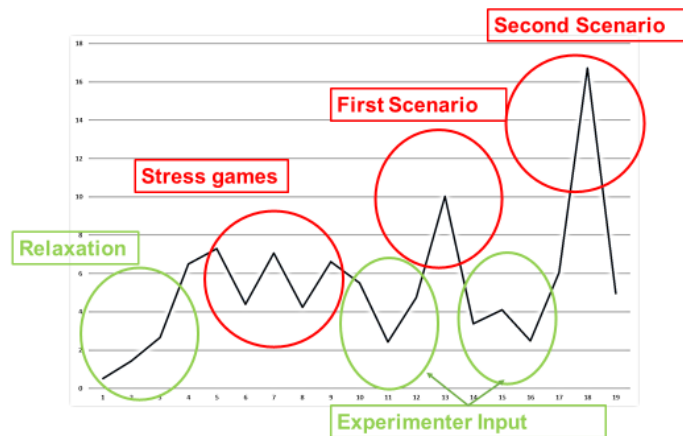


Figure 4: LF/HF during the whole experiment.

### 6.7. *Feedbacks of observations on the overall experiment*

Observations make it possible to identify a certain number of clues through the verbatim, such as comments on the actions performed, laughter, sighs, humming and other paraverbal manifestations that accompany the participants' gestures during interaction with the tablet, or even postures and co-verbal gestures. Two levels of analysis were carried out: a first level of observation, captured during the experimentation with the live video stream, then a second reading based on the video recordings of the experiment (videos from the Intelligent House cameras and 360° camera installed on the tablet (See Figure 2).

In the case of this participant, skilled with digital tools, many elements show his ability to execute scenarios (whistles, relaxed attitude when stating the results - crossed hands and elbows on his knees, verbatim like "Hop! Un de fait!"<sup>9</sup>). In another example, the participant goes to the place where the task is to be performed while reading the instructions (tablet in the right hand, paper in the left hand, all while walking). However, when he encounters some difficulties, there are changes in his postures (bust forward, hand grabbing the chin), in verbatims (annoyance manifested with expressions such as "Mal fait!"<sup>10</sup>) or in para-verbal manifestations (many signs).

## 7. **Towards a model of data crossing**

### 7.1. *Theoretical background of the present data mixing*

The need to mix quantitative and qualitative data seems essential for a better understanding of the behaviors and mechanisms of appropriation of technological devices of people with disabilities. Compared to Creswell's classification [14], our approach to processing the data collected in the MAN project is of the complementary and explanatory design type. Indeed, the multidisciplinary team addresses the issue of digital accessibility by taking into account several data sources (technological profile, cognitive profile, postural attitude, etc.) to analyze the execution of the scenario, in this sense the design is complementary. Data analysis can also be of an explanatory design type in this sense, where human-machine interaction specialists interpret interaction errors according to postural attitudes or stress conditions. However, this aggregation of multidimensional data must be carried out methodically according to an axis of temporality, data weighting and data combination mechanism.

### 7.2. *Overall scheme of the data mixing analysis methodology*

A specific method of data analysis has been designed. It is based on the relationship between the indicators assessed in the MAN method, the data sources used and the types of data collected. The six indicators proposed in the MAN method are the user's social relationship, the user's motivation in the use of technologies, the appropriation effect induced by experience, psychosocial behaviors and attitudes, usability and utility.

For each indicator, relevant data sources were identified according to their nature: main (**MAIN** code), complementary (**COMP** code) or secondary (*Sec.* code) (see Tab. 2). A primary data source is a data source necessary to determine a value for the indicator in question. It is generally a data source usually identified in the literature as such. A value cannot be given to the indicator in the absence of this data source. There may be several main data sources for the same indicator. In this case, this means that the indicator necessarily feeds on the mixing of these data. A complementary data source is an important but not necessary data source for the indicator. The use of this data source allows the value obtained from the main data sources to be refined. A secondary data source is a data source that is not necessary for the given indicator but which could provide information, albeit probably marginal, to support the main and complementary data sources. The data sources used in the MAN method are listed in Tab. 2.

### 7.3. *Table of the indicators and the data mixing*

For each indicator, the tools and methods used are explained. The participant's social relationship focuses on the user's socio-professional, socioeconomic, demographic, cultural, and health profile, as well as their general attitudes and skills towards technologies. The main data sources are the profile questionnaire (quantitative data) and the interview (qualitative data) conducted prior to the experimental phase. This data is independent of the situation in which the user is then placed for the evaluation of the technological device.

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<sup>9</sup> "Hop ! One done !"

<sup>10</sup> "Wrong done!"



#### 7.4. Illustrative crossing using the ELAN annotation tool

To achieve the cross-referencing of the data presented individually in the previous paragraph, the multidisciplinary team of the MAN project has chosen the ELAN annotation tool. This tool allows us to display up to four video sources at the same time, synchronize them, and annotate them by allowing us to create as many lines of annotation, with the possibility of creating dependency links. Thus, it is possible, for example, to annotate the activity, the sub-activities and the phenomena observed from the 360° video.

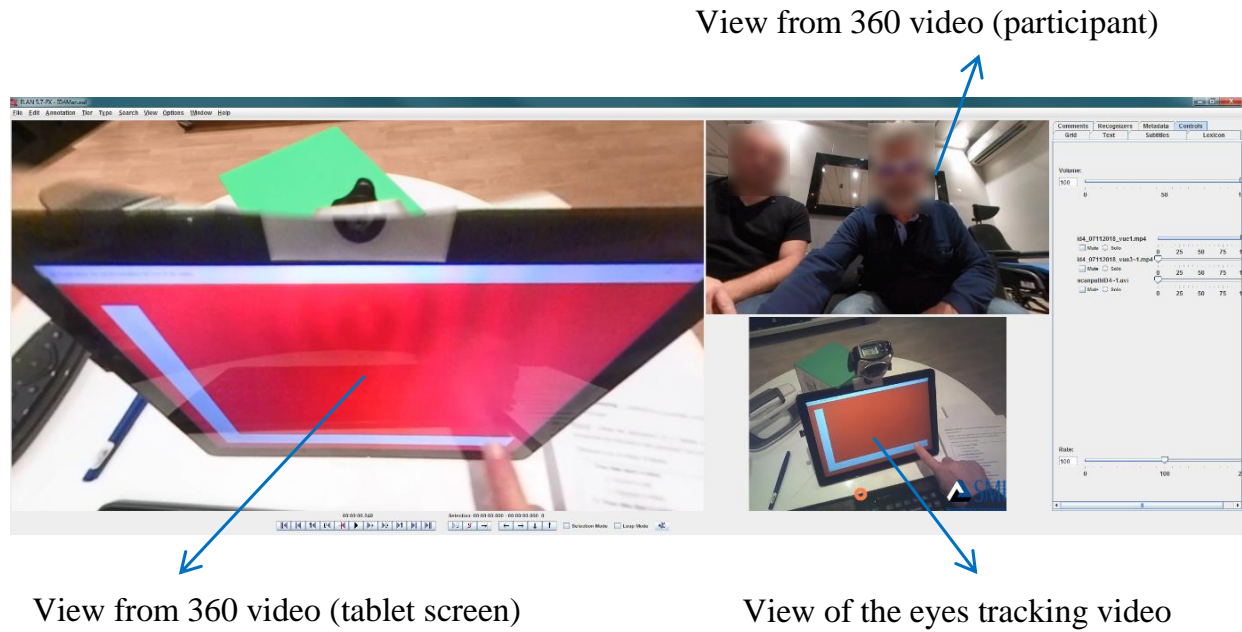


Figure 5: Synchronized videos used in ELAN software.

Figure 5 shows the three videos selected for annotation under the ELAN software. These correspond to two views extracted from the 360° video camera (view from the participant and view of the tablet screen) and the video collected by the Eye Tracking device. This last view allows apprehending the events that can occur in the environment and disturb the participant in his activity. We have set up a procedure to synchronize the data. Here the participant must perform an L letter on the touch screen which will serve as a reference time for data analysis.

The hierarchical reference model of the participant's activity annotations is currently being specified: three levels have been selected corresponding to the activity, sub-activity and phase level as shown in Figure 6. The activity represents the activity that the participant does, the sub-activity means what he does during the activity and the phase level represents labels related to the type of data, for example, mobility act, physical actions on environment objects, posture, verbal communication, non-verbal communication, free comments... during the activities performance. The ELAN annotation tool thus makes it possible to define a multimodal annotation for each of the data collected in the MAN method. These temporal annotations will delimit the calculation intervals of the variables **PRINC**, **COMP** and *Sec* described in Figure 6.

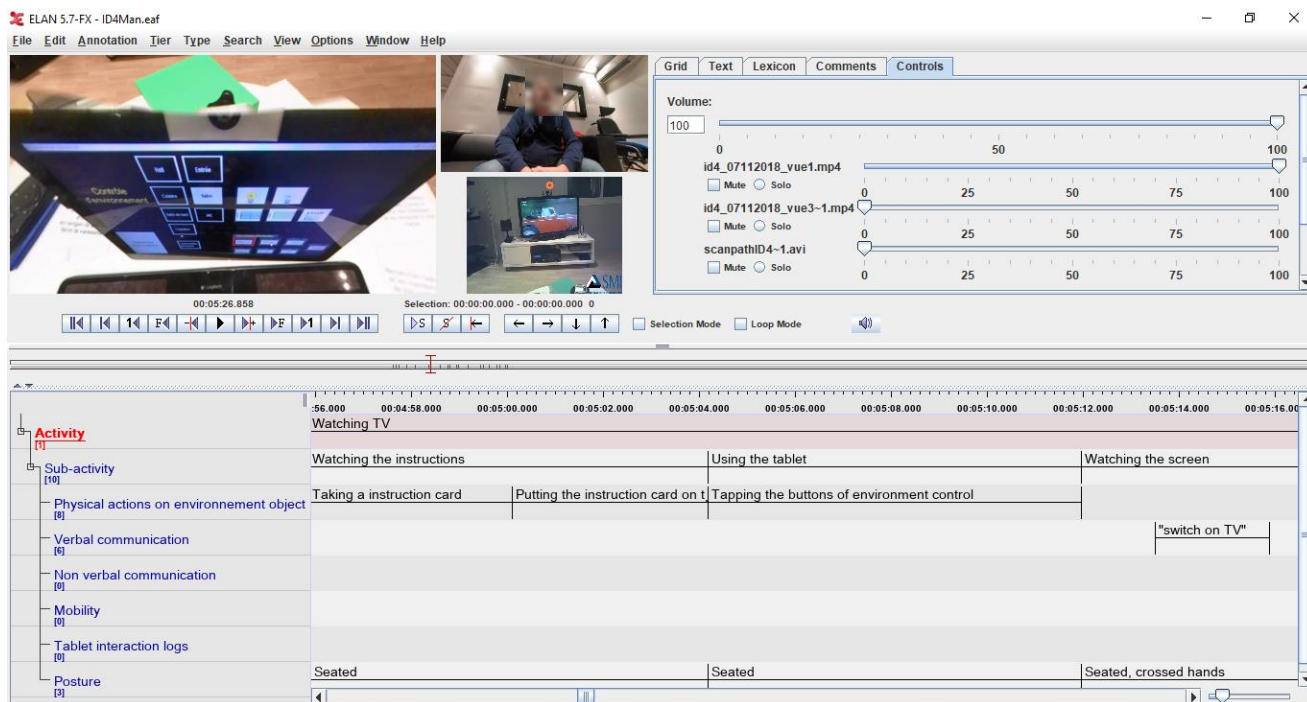


Figure 6: Annotations of activities under the ELAN software.

## 8. Conclusions et Perspectives

In a social context where digital is becoming increasingly important in our daily lives (administrative procedures, interpersonal communication, information seeking, etc.), MAN is an ambitious project through the systemic approach and the range of qualitative and quantitative data proposed to better understand digital accessibility for older people and/or people with disabilities. Because of its original architecture, it raises important methodological issues. Indeed, the MAN project mobilizes researchers from extremely varied disciplines. It is based on mixed methodologies, which requires a complex investigation protocol and instrumental equipment, allowing for multidimensional data collection. Qualitative tools (profile, questionnaire, interviews and observations) and quantitative tools (activity log, postural attitude, eye tracking, heart rate and video and audio data) are justified and illustrated for a participant. Once synchronization is completed, it is now time to realize a data analysis in relation to the two conceptual models (complementary design and explanation) for the definition of the six indicators for characterizing the behaviour of the person using digital technology as well as its usability and utility. The conceptual model for obtaining these indicators is an important contribution, thus revealing all the richness and added value of the multi-stakeholder and multi-methods MAN methodology. The first perspective is the specification of a multi-data annotation model taking into account all the data and its implementation on all participants with the ELAN annotation tool. The second perspective is to extract the data from the multi-data annotations and infer by the implementation of learning methods a single result for the indicators identified by the MAN consortium.

### Acknowledgement

The consortium also thanks the participants in the pre-tests and MAN's experience. The consortium thanks also CNRS (défi AUTON) for founding this project.

### Conflict of interest statement

There is no conflict of interest

### Role of the funding source

This research received grant from the Mission pour l'Interdisciplinarité du CNRS (défi AUTON) in 2016, 2017 and 2018, as well as a grant from the "Maison des Sciences de l'Homme et de la Société" of Toulouse (France) in 2019.

## References

- [1] C. Michel, M-E. Bobillier-Chaumon, and F. Tarpin-Bernard, "Fracture numérique chez les seniors du 4e âge.", *Les Cahiers du numérique* 5, no. 1 (2009): pp. 147-168
- [2] A. Lecroat, O. Froment, C. Marbot, D. Roy, "Projection des populations âgées dépendantes." Ministère des affaires sociales, DRESS, dossier solidarité et santé, 43, 2013.
- [3] T. Coughlan et al., "Current issues and future directions in methods for studying technology in the home", *PsychNology Journal*, 11.2, 2013, p. 159.
- [4] H. Petrie, N. Bevan, "The Evaluation of Accessibility, Usability, and User Experience.", *The universal access handbook*, 1, 2009, p. 1.
- [5] ISO 9241-210. (2010) Conception centrée sur l'opérateur humain pour les systèmes interactifs.
- [6] A. Vermeeren, et al. "User experience evaluation methods: current state and development needs." *Proceedings of the 6th Nordic conference on human-computer interaction: Extending boundaries*. ACM, 2010, p. 521.
- [7] A. Holzinger, M. Ziefle, C. Röcker, "Human-computer interaction and usability engineering for elderly (HCI4AGING): introduction to the special thematic session", *International Conference on Computers for Handicapped Persons* Springer, Berlin, Heidelberg, 2010, p. 556.
- [8] L. Motti, N. Vigouroux, P. Gorce, "Interaction techniques for older adults using touchscreen devices: a literature review from 2000 to 2013", *Journal d'Interaction Personne-Système (JIPS)*, AFIHM, 3.2, 2014, p.1.
- [9] J. Nielsen, *Usability engineering*. Elsevier, 1994.
- [10] ISO ISO/TR 16982. (2008) Ergonomie de l'interaction homme-système. Méthodes d'utilisabilité pour la conception centrée sur l'opérateur humain.
- [11] N. Vigouroux, E. Campo, N. Lompré, F. Vella et al, "Démarche de co-conception d'une méthode d'observation et d'évaluation multidimensionnelle de l'accessibilité au numérique », *Tic&société*, 12.2, 2018, p. 151.
- [12] M. R. Guével, J. Pommier, (2012). "Recherche par les méthodes mixtes en santé publique : enjeux et illustration", *Santé Publique*, 1, vol. 24, 2012, pp. 23-38.
- [13] R.B. Johnson, A.J. Onwuegbuzie, "Mixed Method Research: A Research Paradigm Whose Time Has Come" *Educational Researcher*, 33, 2014, pp.50-60.
- [14] J. W. Creswell (2003), *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, Second Edition, Sage Publications, pp 3-26.
- [15] B. Aldebert, A. Rouzies, "L'utilisation des méthodes mixtes dans la recherche française en stratégie : constats et pistes d'amélioration", *AIMS* 2011, [https://www.strategie-aims.com/events/conferences/4-xxeme-conference-de-l-aims/communications\\_by\\_author?author=Aldebert+B%C3%A9n%C3%A9dicte](https://www.strategie-aims.com/events/conferences/4-xxeme-conference-de-l-aims/communications_by_author?author=Aldebert+B%C3%A9n%C3%A9dicte)
- [16] J. W. Creswell, "Advances in Mixed Methods Research", *Keynote at the 2016 CAQD conference*, <https://www.youtube.com/watch?v=dR2QU2pZcLU> (2016).
- [17] G.L. Albrecht, J.-F. Ravaud, H.-J. Stiker, "L'émergence des disability studies : état des lieux et perspectives". In: *Sciences sociales et santé*. Volume 19, n°4, 2001. pp. 43-73.
- [18] M. Bujold, Q. N. Hong, V. Ridde, C. J. Bourque, M. J. Dogba, I. Vedel et P. Pluye, "Oser les défis des méthodes mixtes en sciences sociales et sciences de la santé", *84e Congrès de l'ACFAS*, 2016, 267 p.
- [19] L. Caroux et al, « MAN : Mise en place d'une méthode d'évaluation croisée de l'accès aux ressources numériques », *Handicap* 2018, 10ème édition, Paris, France, p. 211.
- [20] J.P.O. de Sardan, *La rigueur du qualitatif: les contraintes empiriques de l'interprétation socio-anthropologique*, No. 3, Editions Academia, 2008, p. 368.
- [21] Y. Charlon, W. Bourennane, F. Bettahar, E. Campo. "Activity monitoring system for elderly in a context of smart home". *IRBM BioMedical Engineering and Research, Special Issue: Digital technologies for healthcare*, 34.1, 2013, p. 60.
- [22] A. Piau, *Méthodes d'évaluation multidimensionnelle et de travail collaboratif pour le développement des technologies de prévention de la dépendance des sujets âgés*, Diss. Université fédérale, Toulouse III, 2016.
- [23] R.B. Johnson, A.J. Onwuegbuzie, L.A. Turner, "Toward a definition of mixed methods research.", *Journal of mixed methods research*, 1.2, 2007, p. 112.



- [24] E. Bougeois, J. Duchier, F. Vella, M. Blanc Machado, A. Van Den Bossche, T. Val, N. Vigouroux, E. Campo, "Post-test perceptions of digital tools by the elderly in an ambient environment", International Conference On Smart homes and health Telematics (ICOST), Springer Cham, Wuhan, China, 2016, p. 356.
- [25] A. Tlija, D. Istrate, A.-E. Bennani, H.H. Ngo, S. Gattoufi et al., "Monitoring chronic disease at home using connected devices.", SoSE, 2018, IEEE, 2018, p. 400.
- [26] J. Jacquier-Bret, P. Gorce, G. Motti Lilian, N. Vigouroux, "Biomechanical analysis of upper limb during the use of touch screen: motion strategies identification", *Ergonomics*, 60.3, 2017, p. 358.
- [27] L. Dupuy, C. Consel, H. Sauzeon, "Self determination-based design to achieve acceptance of assisted living technologies for older adults.", *Computers in Human Behavior*, 65, 2016, p. 508.
- [28] C. Lallemand, V. Koenig, G. Gronier et al, "Création et validation d'une version française du questionnaire AttrakDiff pour l'évaluation de l'expérience utilisateur des systèmes interactifs", *Revue européenne de psychologie*, 65.5, 2015, p. 239.
- [29] L. Caroux, L. Le Bigot, N. Vibert, "Impact of the motion and visual complexity of the background on players' performance in video game-like displays". *Ergonomics*, 56, 2013, p. 1863.
- [30] A. Van Den Bossche, N. Gonzalez, T. Val, D. Brulin, F. Vella, N. Vigouroux, E. Campo, "Specifying an MQTT Tree for a Connected Smart Home", International Conference On Smart homes and health Telematics (ICOST 2018), Singapore, Springer, 2018.
- [31] N. Avouris, G. Fiotakis, G. Kahrmanis, M. Margaritis, V. Komis, "Beyond logging of fingertip actions: analysis of collaborative learning using multiple sources of data", *Journal of interactive learning research JILR*, , Special Issue: Vol. 18, n°2, pp. 231-250, 2007.
- [32] M-N. Lamy, "Multimodality in online language learning environments: looking for a methodology », In Baldry, Anthony Montagna, Elena (dirs.), *Interdisciplinarity perspectives on multimodality: theory and practice*", Proc. of 3rd Intern. Conf. on Multimodality, Campobasso: Palladino, pp. 237-254, 2007.
- [33] A. Van Den Bossche, N. Gonzalez, T. Val, D. Brulin, F. Vella, N. Vigouroux, E. Campo, "Specifying an MQTT Tree for a Connected Smart Home", International Conference On Smart homes and health Telematics (ICOST 2018), Singapore, Springer, 2018, pp. 236-246.
- [34] F. Vella, M. Blanc Machado, N. Vigouroux, A. Van Den Bossche, T. Val, "Connexion du Middleware MiCom avec l'interface tactile InTacS pour le contrôle d'une smart home", Journées francophones Mobilité et Ubiquité (UBIMOB 2016), Lorient, France, Telecom-Sud, (support électronique), 2016.
- [35] N. Vigouroux, É. Campo, N. Lompre, F. Vella, L. Caroux, J. Jacquier-Bret, D. Istrate, P. Gorce, N. Pinede, M. Sacher, A. Serpa, A. van den Bossche, "De l'intérêt de développer une vision systémique dans la conception d'une méthode d'observation multimodale pour l'étude de l'accessibilité numérique avec des personnes en situation de handicap.", dans *De la démocratie sanitaire à la démocratie en santé, Vers la construction d'une « handicratie », pour un meilleur accompagnement des personnes en situation de handicap*, Sous la direction de Claude Dussart, Mai-Anh Ngo, Valérie Siranyan, Pascal Sommer, Editions LEH, Vol. 1, Novembre 2019.
- [36] M. F. Folstein, S. E. Folstein, P. R. McHugh, "Mini-mental state: A practical method for grading the cognitive state of patients for the clinician.", *Journal of Psychiatric Research*, 12, 1975, pp. 189-198.
- [37] D. Wechsler Wechsler Memory Scale-Third Edition. San Antonio, TX: The Psychological Corporation, 1997.
- [38] D. Cardebat, B. Doyon, M. Puel, P. Goulet, Y. Joannette, "Formal and semantic lexical evocation in normal subjects. Performance and dynamics of production as a function of sex, age and educational level". *Acta neurologica belgica*, 90(4), 1990, pp. 207-217.
- [39] L. Mcatamney, E. Nigel Corlett, 1993. "Rula: A survey method for the investigation of work-related upper limb disorders." *Applied Ergonomics*, 24 (2), 91-99.
- [40] A. Tlija, D. Istrate, A. Badii, S. Gattoufi, A.-E. Bennani, K. Wegrzyn-Wolska, "Stress Level Classification Using Heart Rate Variability", *Advances in Science, Technology and Engineering Systems Journal*, Vol. 4, No. 3, 38-46 (2019), pp. 38-46.
- [41] A. Queirós, A. Silva, J. Alvarelhão, N. P. Rocha, A. Teixeira, "Usability, accessibility and ambient-assisted living: A systematic literature review" *Universal Access in the Information Society*, 14(1), 2015, pp. 57-66. <https://doi.org/10.1007/s10209-013-0328-x>
- [42] D. Servant, J.C. Lebeau, Y. Moustier, M. Hautekeete, R. Logier, M. Goudemand, « La variabilité cardiaque : Un bon indicateur de la régulation des émotions », *Journal de Thérapie Comportementale et Cognitive*, Volume 18, n° 2, pages 45-48 (juin 2008), Doi : 10.1016/j.jtcc.2008.04.003