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Xassess: crossdisciplinary framework in user-centred design of assistive products

Teresa Blanco[a,b], Alfredo Berbegal[c], Rubén Blasco[b] and Roberto Casas[b,d]

[a]Aragon Institute of Engineering Research, University of Zaragoza, Zaragoza, Spain; [b]Department of Design Engineering and Manufacturing, University of Zaragoza, Zaragoza, Spain; [c]Department of Educational Sciences, University of Zaragoza, Zaragoza, Spain; [d]Department of Electronic Engineering and Communications, University of Zaragoza, Zaragoza, Spain

ABSTRACT
The design of assistive products (AP) is a challenging process that gathers a wide variety of agents with different objectives and backgrounds. This complex scenario demands reflexive and multireferential methodologies, where assessment is essential to make steady progress. We present Xassess, a specific methodological framework for assistive product design that interweaves different phases and types of assessments; it is materialised in a set of tools to be used individually or conjointly. We validated our proposal in a real project, developing an online social network for the sup- port of people with neurodegenerative illnesses with three different scenarios running in parallel. Main conclusion is that the methodology contributes not only to achieve better results, but also to optimise the global process of managing the design of AP. Assessment should be considered from the beginning of the project and interweaved at every stage, include the vision of all the disciplines involved in the project, merge qualitative and quantitative methodological approaches, and serve as enabler of the shared understanding among different worlds. As Xassess also allowed us to see innovation from a different perspective, we encourage its use as a design guide for Design for All and to tailor it to other design realms.

KEYWORDS
Design methodology; design management; evaluation; interdisciplinarity; shared understanding; universal design; design for all

1. Introduction

Assistive products[1] (AP) play an increasing role in the lives of people with disabilities, enabling their well-being by offering new opportunities and choices, facilitating communication, improving personal safety, etc. The design of APs is an especially challenging process that must unavoidably consider end-users' subjective well-being as a key objective. The difficulties lie in many factors, such as user singularity, the need for an extensive multidisciplinary background of the designer, or wide variety of actors, involved with different objectives throughout the process. Considering this, the design process requires conscious and elaborate methodologies to transform initial user needs into a reality.

CONTACT Teresa Blanco tblanco@unizar.es

Assessment is of key importance in this process to determine the impact on a user's life in terms of effectiveness, social significance, and subjective well-being (Jutai et al. 2005). In this context, subjective well-being is usually equated with quality of life, as a complex concept that is highly subjective and consequently difficult to assess. Schalock, Bonham, and Verdugo (2008) model quality of life that takes into consideration building factors, such as independence (personal development and self-determination), social participation (interpersonal relations, social inclusion, and rights), and well-being (emotional, physical, and material). Therefore, if assessment is usually a highly sensitive issue, in the case of APs, assessment focus and philosophy are even more sensitive. This is because, besides the inherent subjectivity of the term quality of life, there are factors and constraints intrinsic to the assessment of APs that hinder the interpretation of conclusions (Martin et al. 2008), and strongly influence design objectives and outcomes. In this context, the design process includes particular considerations among which we can highlight the following:

- The *design object* has to give answer to a highly complex reality, due to (i) *the well-being inter-subjectivity*. It is a common objective of an AP to improve the quality of life, not only for direct users (people with special needs), but also for their relatives and environment. This turns well-being subjectivity into well-being inter-subjectivity, as it is not built from a unilateral perspective, but from a kaleidoscope of perceptions; (ii) *the variance of user characteristics***.** Usually, in design certain homogeneity among users' profiles is often presumed; nonetheless, in AP each person is unique in his/her functionalities, with a high variability of capacities even for the same type of disability, so generalisations cannot be made. To this should be added, the *multiplicity of user profiles*. Very often, the use of the product concerns not only the person with disabilities, but also relatives, healthcare professionals, or caregivers, so the design has to serve to different capacities and expectations; and (iii) *the gap between the user and his/her well-being*. The distance between the user and his/her expected well-being is usually much larger when considering APs. Well-being in this context is more than an added value.
- This obviously influences the *design process*, within which the following issues also play a determining role: (i) *the user stigmatisation*. An AP is usually prescribed (not chosen) with consideration for functional issues rather than personal preferences or emotional responses (Desmet and Dijkhuis 2003). This has a negative effect because the identity created by the product would not necessarily correspond to the image the user has or wants to portray (Olander 2011). Thus, something improving the physical or sensorial well-being can become counter-productive in terms of emotional well-being, as it can be perceived as stigmatising; (ii) *technological user exclusion*. The lack of technology literacy of people with special needs (e.g. elderly) usually excludes them from participation in the digital age (Lim 2010). This makes taking advantage of the latest technological advances dramatically difficult, and also increases (iii) *the gap between the designer and the user*. The cultural designer's prejudices, the lack of knowledge about the disability, and the tremendous gulf in expertises make it difficult to empathise with the end user (Wu 2010; Batchelor and Bobrowicz 2014); and (iv) *the user relationship complexity*. Engaging end users in the design process is a challenging duty (Weightman et al. 2010). The information process is more complex because sometimes we cannot have the user's direct testimony but a proxy's interpretation (e.g. caregiver, relative, or therapist); this is a common procedure (Artoni et al. 2011) but it implies not few limitations (Dawe 2007).

This influences not only the evaluation, but also all the collaborative design processes that must be adapted to the users' reality (Francis, Balbo, and Firth 2009).

- Finally, *product assessment* needs to face many challenges, including: (i) *the multiplicity of assessment indicators*. Although a primary objective, well-being is not the only success indicator in the assessment; other dimensions, such as associated costs or economic evaluation, need to be considered in the design (Harris and Sprigle 2003); (ii) *the variance of context and sampling***.** As it happened in design object, each person is unique in his/her functionalities with a high variability of capacities even for the same type of disability. Depending on individual particularities and on design policy, the user could participate in the process as mere user, tester, informant, or design partner (Guha, Druin, and Alan Fails 2008). In the case of multiple user profiles, assessment strategies must also be adapted (Shah and Robinson 2008); (v) *the measurement of moving targets*. For example, how well a user uses a device or his/her opinion might vary from day to day depending on the physiological and emotional states and disability's effects (Johnson, Clarkson, and Huppert 2010); (iv) *the limitations of assessment instrumentation*, which are not usually adapted to people with special needs; and (v) *the Hawthorne effect*, the positive response of participants due to the special treatment they are receiving by the evaluator (Diaper 1990) is especially relevant for people with special needs.

Literature covers extensively various areas on how assessment should be performed once the product is developed. DeRuyter (1997), Fuhrer et al. (2003), Parette et al. (2006), Lenker and Paquet (2003), and Hersh (2011) focus on assistive technology ecosystem comparing different models and frameworks for an effective intervention. Considering that the assessment is of key importance not just to validate results, but as a part of the design process from the beginning, how the assessment is understood and applied would result in different product concepts: from the former 'design for disability' as a design with a clinic background aiming to eliminate handicaps, to the current Inclusive Design, Design for All, or Universal Design approaches (Preiser and Ostroff 2001; Clarkson et al. 2003).

In the following sections, we provide an overview of the assessment concept, discussing its historical, conceptual, and methodological plurality (qualitative versus quantitative) and the strategies, techniques, and instruments associated with this. Then, we present our specific proposal for AP assessment, considering all the dimensions throughout the design and development process: who, what, why, when, and how to assess. Finally, we present and discuss the results derived from the application of said proposal to several real projects with real deployments and users along many years.

2. A historical overview of assessment methodologies

To understand the state of the art in the theoretical field of evaluation as a discipline, it is appropriate to roll back to the epistemological development of assessment strategies, as they represent new levels of perspectives and lenses that overlap with those derived from factors conditioning the field of AP. Four generations of evaluation have been specifically studied in the recent history of evaluation and evaluation research (Escudero 2003). In every generation, we see different scientific perspectives with diverse purposes, methods, and methodological ascriptions. Table 1 broadens Lincoln and Guba (1989) and Lai (1991) insights and shows how each generation is characterised by their particular approach,

Table 1. Evaluation generations' insights.

	1st generation:	2nd generation:	3rd generation:	4th generation
Approach	Technician evaluation	Analytical evaluation	Value evaluation	Responsive and socio-constructivist evaluation
Role of evaluator	Technical expert, human instrument, and human data analyst	Describer, illustrator, & historian	Judge, mediator of judgemental process	Collaborator, learner, teacher, reality shaper, change agent, among others
Relationship with the user	Measurement	Description	Judgement	Interaction
Key characteristics	Determine the change effectiveness of evaluative programme	Determine the change Effectiveness of evaluative program	Standards and criteria objective evaluation	Users/stakeholders demands, concerns, and matters Primarily qualitative methods; no causally inferential statistics

the role played by the evaluator and his position with regard to the user, the specific key features, and the objectives of the action.

This history deals with a conceptual and methodological plurality. The models are usually classified into two large groups: quantitative and qualitative (Guba and Lincoln 1981; House 2010). Qualitative implies an emphasis on processes and meanings, on the socially constructed nature of reality, and seeks answers to questions that stress how the social experience is created and given meaning. In contrast, quantitative approaches emphasise the measurement and analysis of causal relationships between variables, not processes. Both use different ways, forms, media, and means to communicate their findings (Denzin and Lincoln 1994).

Sometimes, when we work in a multidisciplinary group, the moment of design evaluation could drive to a gap among professionals with a diversity of interests, academic affiliations, and references; this factor is added to the AP multiplicity previously described. Table 2 shows the magnitude of said dichotomy and points to the necessary negotiation process to reach an agreement.

Currently, this direct method-paradigm articulation has been strongly criticised, especially by scientific communities in evaluation and evaluation research domains (Teddlie and Tashakkori 2003), but also in the engineering design (Chen and Lee 1993) and technology fields (Venkatesh, Brown, and Bala 2013). The alternative considers that there is no reason for a rigid and direct affiliation and, consequently, that methodological uses depend on how we interpret the entire design process and whether these data are useful for the design objectives; in summary, flexibility and adaptability of methodologies is the most suitable solution.

In conclusion, both methodological approaches generate knowledge and get stronger combined with one another, providing perceptions that would be impossible to achieve separately. Nonetheless, we have to explain how we plan to integrate them into our assessment design. It is necessary to first emphasise the difference between eclectic uses of methodology and combined and pertinent uses of mixed methods (Brannen 2005), regarding our interests and decision-making for the evaluation.

Managing assistive concepts we run the risk of being directly translated into certain methodological preferences (justification and demonstration imperatives), responding to a specific tradition of science (objective and quantitative). However, are we willing to open

Table 2. Quantitative and qualitative cross-methodological dialog.

		Quantitative methodology	Qualitative methodology
Ontology	Paradigm	Positivist	Constructivist
	Object	Social facts	Significations
	Social reality image	Static and external to actors	Procedural, constructed by actors
Epistemology	Reasoning modes	Nomothetic	Ideographic
	Nature of data	Reliable	Deep
	Linked terms	Experimental	Ethnography
		Control/test	Field work
		Measure	Sense construction
		Outside perspective	Inside perspective
		Empiricism	Naturalism
		Mathematical models	Hermeneutic models
		Verifiable	Descriptive
		Situational standardisation	Case study/life story
		Hypothetical generalisation	Ecological comprehension
		Etic	Emic
		Statistical approach	Narrative approach
		Focus study	Holistic
	Linked concepts	Variability	Mean/signification
		Explanation	Understanding
		Expert statements	Profane and common sense
		Studied situation	Definition of the situation
		Product	Process
		Scientific authority	Everyday life evidences
		Logical expectations	Negotiated order
		Scientific construction	Social construction
		Hypothetic-deduction	Practical expectations
		Prediction	Adaptability
		Replication	Grounded theory
		Reliability	Dependency
		Effectiveness	Conformability
		Validity internal	Credibility
		Validity external	Transferability
		Objectivity	Inter-subjectivity
	Theoretical affiliations	Functionalism	Phenomenology
		Structuralism	Hermeneutic
		Logical empiricism	Symbolic interactionism
		System theory	Ethnomethodology
		Behaviour	Culture
		Realism	Idealism
	Academic affiliations	Positivistic sociology	Comprehensivesociology
	Disciplinary boundaries	Political sciences	Cultural anthropology
		Experimental psychology	Humanistic psychology
		Economy	History
Methodology	Language	Numbers	Words
	Subject	Sample	Case
	Data collection	Experiments	Field work
		Quasi-experiments	Document analysis
		Surveys/tests	Focus group
		Structured interview	Unstructured interview
		Structured observation	Unstructured and participant observation
		Data registration	Narrative writings Record and transcription
	Data analysis	Statistical	Interpretative reading
		Special phase	Continuous phase
		Deductive	Inductive
		Checking	Constant comparative
	Report	Descriptive	Narrative

(*Continued*)

Table 2. Continued.

		Quantitative methodology	Qualitative methodology
Evaluation consequences	Evaluation Role	Preparatory	Interpretation's actors exploration
	Evaluator and evaluated people relationship	Distant	Closed
		Neutral	Engaged
	Evaluator position to the people	Outsider	Insider
	Evaluation relationship with theory and concepts	Confirmation	Emergency
	Evaluation strategies	Structured	Unstructured
		Aprioristic designs	Emergent designs
		Project/procedure	Plan/process

our evaluation in order to suit to situations in life? Or do we prefer to evaluate for accounting and accrediting our aprioristic goals? How are we building solutions when we only evaluate their impact from an exclusive methodology? The problem cannot be confined to methodological limitations: we do not evaluate only products, but also how products aim to help and make everyday life easier.

3. Methodological proposal

The high complexity of the nature of AP design and evaluation represents a major challenge in terms of methodological management. The multiplicity standpoint and combination of visions demand a shared and transdisciplinarity working (Scriven 2008). It implies the existence of different worlds with different skills, languages, references, and profiles: in brief, different object worlds (Bucciarelli 1994), which sometimes also meet to dialog among themselves (see Table 3). Traditionally in AP projects, maybe due to these factors, design and evaluation were leaded only from a partial point of view, or else the different disciplines and departments were not integrated in a real interdisciplinary way, being the work partitioned along phases. Typically, the needs assessment phase was conducted exclusively by social/health professionals. This resulted in information that was very extensive and valuable from the sociologic/health perspective, but sometimes lacking some of the relevant data for the design and development phase. Lists of needs were communicated to the design and technical team, who worked in the next phases independently and from an exclusively technical lens, until the final evaluation phase, where social professionals were again involved to 'examine the work'. We could say the information obtained was 'too user-centred', to be handled in phases 'too centred around the product'.

To avoid this, an optimum approach is to plan the evaluation from a transdisciplinary view. In our approach, named Xassess, not only evaluators but transdisciplinary teams of social/health, design, and technical professionals must collaborate for common goals throughout each of the phases, monitoring closely the transition between phases and departments. Otherwise, outcomes of different assessments and consequently the product design itself run the risk of losing focus. The designer should play a key role in this process since, thanks to his holistic training, he can act as a bridge between social and technological spheres.

Table 3. From object worlds to common ground.

	Evaluator world	Designer world	Developer world	Common ground proposal
Methodology	Reasoned and structured mixed-methods	Tendency to qualitative methods	Quantitative methods	Common methodology Common tools and resources Phases interfaces
User view	Knowledge	Inspiration	Validation	Product implications awareness (evaluator)
	Understanding	User-fit	Reliability	Reasoned evaluation awareness (designer)
	Empathy	Feasibility	Security	User empathy awareness (developer)
Final objective	Contribution/ service	Contribution/ service	Contribution/ service	Contribution/service common definition
Traditional roles	Information	Conceptualisation	Implementation	Codesign iterations Different stages of evaluation (partial evaluations to decision-making and final evaluation to validate)
Product view	Desires	Pragmatic/syntactic/ semantic object levels	Technological constraints	Different stages of evaluation (partial evaluations to decision-making and final evaluation to validate)
Product expectations	Needs solver	Conceptual advance	Technological competitiveness	Requirements priorisitation and agreement

Nonetheless, the effective implementation of this collaborative approach is not exempt of difficulties. It requires coordination and consciousness at various levels of the project, considering all barriers and enablers that it implies (Kleinsmann, Buijs, and Valkenburg 2010), and implementing different approaches to ensure that understanding is truly shared. Shared understanding barriers between disciplines should be solved or softened by fostering a common ground. The key factors of Xassess include an interdisciplinary grasp from the project initiation, a codesign process based on iterative stages and shared product assessment, and the establishment of a common methodology based on discussion and agreement, with common tools, common language, and common objectives.

The origin of our methodological proposal, presented in following sections, was to facilitate the common ground among the coordinators of different work packages in real projects and finally led to the definition of a specific protocol and the design of a number of tools that aim to streamline and facilitate the management of both coordinators and professional teams in transdisciplinary projects.

Table 4 illustrates the way we structure Xassess; the tools developed and its situation in this paper; and how these tools can be used depending on the step and objective. In next subsections, we illustrate each of these steps.

3.1. Who, what, and why to assess

It is evident that assistive technology aims to impact the lives of users and their environments; nevertheless, as DeRuyter (1997) indicates and contrary to mass products, it is not evident how and who decides the assessment outcomes: To what extent can we say an AP works as intended? What does 'working' mean? For whom and for which scenarios should it work? Thus, within a project framework, it is essential to consider and agree on the answers

Table 4. Assessment planning.

Step		Description	Resource	Resource uses
What/who/ why	Objectives definition	General objectives of the project are reviewed and agreed to at all levels by all departments Stakeholders are defined and organised into a hierarchy, according to Table 5 (who/why/what). It includes the users and scenarios modelling	Table 5 (who/why/ what)	*As a definition tool*: in very early stages, to define the project scope and needs assessment phase; during or after needs phase, to define indicators *As a reminder*: in concept and development phases, about the global design objectives *As a checklist*: in final evaluation, for validation *As a management tool*: along the project, to ease shared understanding among disciplines
	Indicators setting	The objectives are used to define the set evaluation measures (indicators) in each area of interest (person match technology, technical and impact) The indicators will show evidence of project success and will serve as a starting point in the needs phase		
When	Assessment planning	Definition of global assessment criteria and macro-methodology Planning of the evaluation for each phase, valuing budget, time and users constraints. Determine the singular demands of each phase and innovation cycle, so it will have an intrinsic nature related to the entire process. Reserve time and budget resources both for aprioristic dimensions and for eventual emergent issues This step intermingles with 'how steps'	Table 4 Figure 2 (ad hoc extended version)	(Table 4) *As an aid to decision-making*: to value pros and cons in case of disagreement between coordinators (Figure 2) *As a management tool*: to situate decision-making milestones along the project; to preview the level of completion and the partial objectives of each phase
How (for each phase)	Theoretical level	Determine the three key AP assessment factors for each phase: purpose and objectives, agents and scenarios, and methodological approach Define assessment dimensions to evaluate (based on classification in Section 3.4 and in indicators defined previously) Define the strategies associated to each dimension (based on Figure 3) with their respective instruments and techniques. Define users and scenarios for the phase, based on Table 5	Figure 3 and Tables 6–9 Example in Table 11	(Figure 3) *As management tool*: this resource is useful to provide assessment literacy to other disciplines (Tables 6–9) *As a definition tool*: To define each phase key factors *As a reminder*: about the specific design objectives of each phase *As a checklist*: listing relevant issues that need to be answered in each phase *As a management tool*: to value human resources and to define team tasks; to ease shared understanding among disciplines
	Fieldwork	Identify team members and set their roles Define common vocabulary for multidisciplinary teams Present the tools and methodologies Select participants and scenarios to implement the evaluation Implement Multidisciplinary discussions and meetings Iterations of results analysis and design of instruments (in triangulation strategies) Final results analysis	Field documentation (out of the paper scope)	

to these questions at the beginning of the project. During the entire process, it is mandatory to keep in mind *what* kind of AP product will be under assessment and *who* will be the user(s). Today the need for user-centred design is a matter of course. Nevertheless, much of the existing research into assistive technology practices, and particularly evaluation, could be characterised as 'people-centred' (universal and general issues) rather than 'person-centred' (singular and particular issues) (Scherer 2002). Strategy, or better yet, the compromise between both perspectives, should settle each case taking into account that a design for disability is usually a design for an extreme diversity. This requires a high degree of knowledge of the data, statistics, and basics, just as much as searching for inspiration in particular and nearby stories. Merging *what* and *who* raises more complexity and new considerations, depending on whether the product use is shared with others who are with or without disabilities, whether this sharing is public or private, and whether it implies data security issues, among other factors.

Consequently, Xassess takes into consideration the following: the motivation of the assessment (*why*), who needs the assessment outcomes (*who*), and which aspects of the product need to be assessed (*what*). Although a user's well-being is the final objective, to make the product a reality there are as many visions and answers as there are stakeholders involved in the process. Those we find most relevant in the evaluative environment are sketched in Table 5, as a tool to be used at the beginning – as starting point both in early project definition and after in the design of evaluation – and all along the project – as a reminder or checklist. The table must be adapted to each project, providing a global perspective that serves as communication tool among the multidisciplinary teams, which is useful for the detection of requirements and to facilitate the decision-making process in the design of a product.

3.2. How to assess

In addition to the plurality of dimensions, interests, needs, and demands that we have to deal with, the evaluation should also consider any answers to the question 'how to assess' on each phase and iteration cycle, which resources to use, and how combine and analyse them. So, an assessment plan and implementation requires a clear knowledge of some key factors: the pros and cons of the methodological *approaches*; which *dimensions* are open to evaluate; the *instruments and techniques* to implement the evaluation; and finally, which *strategies* to follow to get the most of all these resources.

Evaluating APs by real users in real scenarios leads to weaknesses and specific problems arising from exclusively performing evaluations by quantitative or quantitative approaches. Mixed methods strategy can overcome this, taking the best method to deal with a variety of conditions and demands (multiple and complex objects) and generating a multifaceted knowledge that supports a full understanding. But how can both approaches be integrated in order to obtain common, convergent, and pertinent results and meanings? The nature of the data we need for our assessment decision-making is the key for our methodological choices. Beyond qualitative and quantitative divide, methodological design for assessing products must make the distinction among strategies, techniques, and instruments.

We can draw three main *strategies*: complementation, triangulation, and combination (Bericat 1998). With the complementation strategy, we shape different images: some of them come from qualitative methodology and others from a quantitative one. Each

Table 5. Different aspects of AT to be assessed per each kind of stakeholder (who, why, what).

Who	Consumer	Provider and designer	Decision-maker
Why	End-users and relatives[a] Healthcare professionals/caregivers and end-user associations[b]	Researchers and designers[c] Industrial stakeholders[d]	Funding bodies and official institutions[e]
Person-technology match: *Usability*: effectiveness, efficiency, and satisfaction in a context of use (ISO/DIS 92411998) *Physiological functioning*: effect in conation, affect, and cognition *Subjective well-being (emotional, physical, and material)*: degree to which people have positive appraisals and feelings about their lives (Fuhrer 2000, 483)	– Does it work? – Is it easy to use? Accessible? Can be used autonomously? Do I like it? Will I identify it as a part of myself? – Will it help me to include myself in the society in an independent way (emancipatory purposes: autonomy and self-confidence)? – Will it contribute to improving my personal development (emancipatory purposes: auto-realisation and auto-determination)? – Does it stigmatise me? Will other people change their behaviour with me as a consequence of the use of this product? – How long will the user be able to use it? – Is it what the user needs? – Does it facilitate or hamper a caregiver's daily work? – Does it reduce a caregiver's anxiety? – Will it modify a caregiver's procedures? – Is it appropriate for the user's level/training? Is it easy to learn?	– Does it work as expected? – Will the potential customers find it useful? – Does it solve/improve the initial problem? – Does it fulfil the usability requirements? – Does it fulfil the suitability and feasibility requirements? – Is its way of use innovative? – Will it give a satisfactory experience to all user profiles? – Will the potential users accept/reject it? – Can a user's disability cause inadequate use of the product?	– Is it enhancing/supporting users/relatives/caregivers well-being? – Does it improve what is already being used? Is there any previous successful case? – Does it fulfil funding program objectives?
Technical aspects: *Manufacturability Reliability:* satisfactory perform for a given period of time when used under specified operating conditions (Blanchard 2004).	– Will companies be interested in manufacturing/offering it? – Is it easy to maintain? – How costly is to repair? – Is it durable? – Is it compatible with others?	– Does it need new/not mature technology, materials, and processes? – Could it be easily manufactured? How much inversion is needed? – Is it technologically reliable enough? – Is it feasible from a manufacturing and economic point of view? – Is it safe to use? – Is it regulations' and standards' compliant?	– Is the technological outcome mature enough? – Will be companies interested in manufacturing/offering it?

Impact: *Cost efficiency*: comparison of the relative costs and effects of the AP *Competitiveness and novelty*: target in mainstreaming/specialised market, position related to the state of the art *Ethical and legal issues*	– Is it worth what it costs? – Is it the best solution for given users? – Will it have financial support from institutions? – Which advantages/drawbacks does it have compared to other solutions I know? – Are ethical or legal implications properly covered?	– Is it something new? – Which advantages/drawbacks does it have compared to the market or state of the art? Does it cover market niches? Is it liable to be purchased? – Does it mean a progress in knowledge? – Will companies be interested in licensing the product? – Can it be strategically important for my business? – Does it match product line/company image? – Which ethical/legal implications should be considered?	– Can its adoption have political/social impact? – Does it reduce public expenses? How much? – Is it something new? – Which advantages/drawbacks does it have to other solutions already established? – Are ethical and legal implications properly tackled?

Notes: *Different assessment scenarios* will determine its motivation, such as: outcomes will be used by supporting institutions to assess a financed project (e.g. an European Commission in a project of the ambient assisted living call); outcomes will be used by decision makers (e.g. politicians that use the results to decide whether the AP is supported by the government; company managers to decide if the company goes for mass manufacturing of the device; etc.). Immersed in the design and development of the AP, we look fot spot a specific product's usability limitations in order to improve it, if it will engage the user, or if product functionalities will satisfy each user profile.

[a] *End users or beneficiaries.* Those that see their functional capabilities increased, maintained, or improved thanks to the use of an AP. Typically we are talking about people with disabilities, elderly people (Stickel et al. 2002), and their relatives (Parette, VanBiervliet, and Hourcade 2000).

[b] *Caregiver and end-user associations.* People with special needs are usually assisted by professional or informal caregivers, who look for different answers from an AP assessment. End-user associations usually share the same interests as caregivers: they look for the benefit of the person with special needs (Dissinger 2003). On the other hand, an AP usually facilitates and improves a caregiver's work, so they must also be considered as a kind of beneficiary and properly defined and classified (Shah and Robinson 2008).

[c] *Designers and researchers* that devote their professional activity to advance in the knowledge of and create new concepts, ideas, and products (Stone et al. 2010).

[d] *Industrial stakeholders* are of great importance as they are the companies that decide to put an AP into the market. They will look for answers related to the market, inversion needed, technological maturity, etc. (Sauer et al. 2000).

[e] *Funding bodies and official institutions* are also interested in the outcome of the evaluation of an AP with a broader perspective as they look for the benefit of the society as a whole (Simpson 2002).

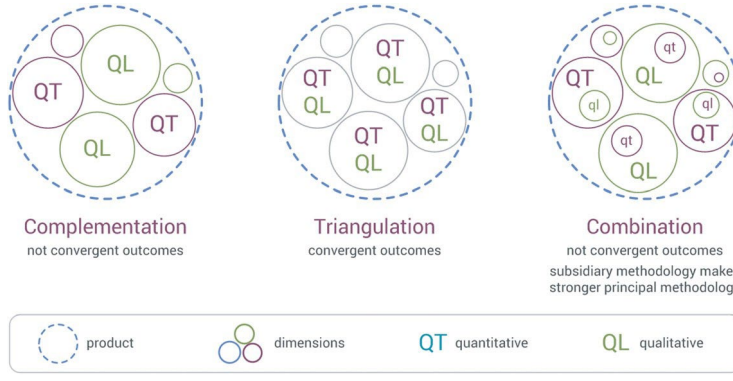

Figure 1. Strategies of methodological integration in relation with product (colour online).

approach illuminates different dimensions and issues of assessment situations, without any methodological overlap. The methodological integration is minimum and the report of results is done in two different languages. If we focus on the same dimension in two different orientations, we can try to integrate both views, and we are carrying out a *triangulation strategy*. Applying two approaches to the same dimension, the outcomes are refined, and each approach reciprocally provides support to the validity and reliability of the results. Finally, the third is the *combination strategy*, in which we integrate one approach into another in a subsidiary way. Depending on the nature of the needs and dimensions we have to assess, we emphasise a methodological approach, preceded by another one. This would be the case of using a questionnaire in a strategic way (preliminary delimitation of conceptual domain by aprioristic and possible indicators; initial closeness to field work, to users, professionals, and associations; etc.) for designing focus groups and in-depth interviews afterwards; or, facing the situation the other way round, using focus groups to identify the majors points to be recovered in a survey.

As in Figure 1, the product or service can be considered a mixture of dimensions to assess; the choice of the dimensions to evaluate and the strategy to evaluate them will influence how assessment methods are interrelated and applied. This figure is used in Xassess mainly to instruct team members involved in assessment (especially those from technical domains) and to allow the strategies agreements.

3.3. When to assess

As we said earlier, the complexity of assistive scenario requires a certain systematisation of the full range of phases, methods, points of view, and factors to consider. Xassess propose to face projects with ad hoc methodology for each project, that usually shares four classical general stages with different assessment milestones and '*n*' iterations, as shown, simplified, in Figure 2. We coincide with Hersh (2010): even when there is a specific stage for evaluation, assessment is needed in every stage of the iteration. Since a proper assessment plan should balance flexibility and structure, the process, as a whole, requires a non-linear logic. We need clear feedback and intercommunication between phases and short cycles, so one spiral system must be articulated for changing, saturating, and defining aprioristic and emergent dimensions.

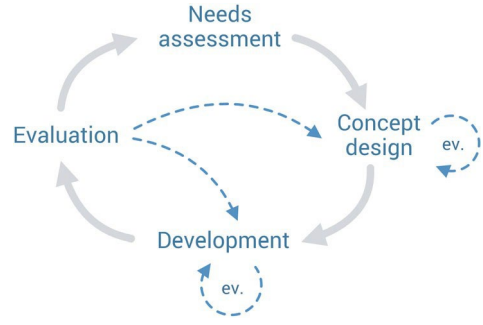

Figure 2. Simplified project development methodology (colour online).

In the same way that objectives, agents, and methodologies differ in each phase, the assessment's nature can change, acquire varied facets, be used to make decisions, evaluate, select, analyse, model, simulate, test, or experiment (Sim and Duffy 2003), and can have diverse inflows and outflows; nonetheless, in every phase, assessment essentially aims at making decisions.

The following subsections describe the distinctive features that assessment acquire in each phase, both in object and objectives, and in the way to carry it out. We also give some examples of application and present the tools we use with transdisciplinary teams following the protocol in Table 4.

3.3.1. Needs assessment phase: looking for knowledge and empathy

Who/what – Data collection and sometimes scientific research are primary objectives to meet the needs of those who are often excluded from product design (Table 6) (Coleman 2001; Beecher and Paquet 2005). Besides the traditional instruments – such as statistics, inquiries, surveys or scientific publications – user models and capabilities databases (Van Isacker, Goranova-Valkova, and Grudeva 2008; Johnson, Clarkson, and Huppert 2010) have prompted the development of inclusive design tools as HADRIAN (Marshall et al. 2010), the inclusive toolkit with the exclusion calculator (Clarkson et al. 2007), userfit (Poulson and Richardson 1998), and NIMID (Blasco et al. 2014).

The other pole of needs phase is immersion, inspiration, looking for team empathising, and engagement with the users' motivations, wishes, aspirations, or emotions. From this perspective, user needs are not so much collected as apprehended with the support of different ways as ethnographic methods, which have gained momentum since design thinking methodologies (Brown 2008) arose; technological simulators, that could be very useful to put the designer in the user's place and to identify real usability problems (Cardoso and Clarkson 2012); and resources to engage with the user emotions (Desmet and Dijkhuis 2003), among others.

It is advisable that at least one member of each department takes part in this process because, besides making the methodology more efficient, it engenders empathy with end users and eases cohesion with other team members; and most important, this allow collect data thinking ahead in the design, and having a proactive approach. With these perspective, the end of the needs phase constitutes and intermingles with the beginning of the next phase.

Table 6. Aspects to be considered in needs phase assessment.

	Purpose and objectives	Audiences/participants/ scenarios	Assessment methodology and issues
Needs assessment	*Knowledge+empathy* Definition of indicators for the subsequent phases Wide knowledge of scientific and statistic reality User competence analysis* Team empathising and engagement with user Inspiration and comprehension of user reality *Questions*: Which are the latest scientific advances on the topic?* Which is the technical and market status of the issue? Which are the relevant statistical data about the problem to solve? Are there any relevant statistical data?* Which are the motivations, wishes, emotions, and aspirations of the users? How users currently deal with the problem?* Homemade solutions?* Can we detect emergent dimensions, features, or restrictions not previously identified?	Small sample of each range of potential users as 'experts in their own context': people with disabilities, elderly people, their relatives, and professional end-users (caregivers and therapists)* In some cases proxies as mediators might be needed* Multidisciplinary professional team lead by an evaluation expert	*Usual strategies*: combination *Mixed methods*: literature review, market studies, quantitative methodologies (capability bases, surveys, observational approaches, etc.) & qualitative methodologies (ethnographies, case studies, life history approaches, etc.) *Issues*: – Absence of prejudices – Collection but also comprehending – Explore scenario; user knowledge – Perceived & suspected needs: derived needs – Specific, common, and transversal or interactive needs. – Needs priorisitation – Person centred supported by people centred*

*Indicate those especially relevant for AT.

How – In the needs assessment, we require a combined methodological approach that allows relevant issues for singular contexts to emerge. We attempt to explore our assistive scenario where users explicitly define, when possible, demanded needs; we refer to them as *perceived needs*. However, needs could be *suspected* by stakeholders, intuitively known (regarding their subjective and intersubjective beliefs, obsessions, expectations, and fears). Finally, as the result of the contact point of perceived and suspected needs, we can also detect *derived needs*. On the other hand, we deal with *specific needs* (regarding illness, disease, and disability lifestyle as well as and professional and institutional cultures), *common needs* (shared needs by some collectives) and *transversal or interactive needs* (produced by assistance and personal interactions, by the communication and collaboration processes among different collectives). Different natures of needs imply the need to carry out different exploration approaches, joined with different strategies of integration and, as a key milestone, determining the relative importance and prioritisation of each one (Afacan and Demirkan 2010).

3.3.2. *Concept design phase: looking for user-fit feasibility*

Who/what – From the project management side, assessment is essential at this stage since it prevents late detection of concept errors and development of solutions that do not fit the user, and therefore avoids economic and temporal upsets (Table 7) (Barton, Love, and

Table 7. Aspects to be considered in concept design phase assessment.

	Purpose and objectives	Audiences/participants clientele/scenarios	Assessment methodology and issues
Concept design	User-fit feasibility Dissonances between user perspectives and the ideated product concepts Level of acceptance/stigmatisation that the product will have among the potential users* Concept feasibility; select alternatives Product semiotics *Questions*: Is it the best solution for real or quasi-real situations in the light of identification needs? Is the concept understandable, suitable, and friendly for the user? Does it fit all disability degrees?* Can we detect emergent dimensions, features, or restrictions not previously identified?	Small sample of each range of potential users as in the needs assessment phase In some cases proxies as mediators or technological simulators might be needed* Multidisciplinary professional team lead by a design expert Experts' panels for technical issues	*Usual strategies*: triangulation, combination *Mixed methods*: collaborative design methodologies, low/medium/high fidelity prototyping, 'Wizard of Oz', cognitive walkthrough (or informal walkthrough for cognitive disabilities), interviews, checklists, etc. *Issues*: – Simulated technology functioning and controlled scenario – A minimum of abstraction from the user is required and sometimes not possible – Concept validation, but not product – Open and flexible assessment

*indicate those especially relevant for AT.

Taylor 2001). The design team needs to ascertain whether the approach is appropriate for the user's needs and perspectives, and refine the product concept that they have ideated, checking for potential concept mistakes (Derelöv 2008), proving the usability and human–machine interaction (Park, Son, and Lee 2008), reviewing the aesthetics, assessing development process time (Isaksson, Keski-Seppälä, and Eppinger 2000), assessing product acceptance, checking ergonomics (Dukic, Rönnäng, and Christmansson 2007), solving doubts that could arise, and (if user, technical, or production tests indicates) remodelling function and form features. Thus, the evaluation here is mainly a decision-making tool that guides 'good design'.[2] User assessment in this phase can be considered a more open and abstract advance from the assessment performed in the evaluation phase, allowing prevalidation and obtaining valuable user feedback. It represents, in short, a special product evaluation where the technology functioning is simulated (by sketches, models, or prototypes), the scenario is controlled (usually it takes place in the lab and for short periods of time), and where users should understand that they are validating a concept, not a real product (Campbell et al. 2007). For that reason, sometimes the result could be limited within the assistive field. An extreme case is that of users with cognitive disabilities that involve limited language abilities, and lack of abstraction degree necessary to evaluate prototypes or participate in hypothetical discussions and scenarios (Cohene, Baecker, and Marziali 2005; Dawe 2007). As we state in Section 1, domain experts and proxies' expertise are important and common but limited resources, so it is indispensable to conjoin it with other tools, either to resort to ad hoc techniques (Lepistö and Ovaska 2004).

How – In this phase assessments must be open and flexible, carrying out design techniques closer to qualitative methodology. Developing AP projects in an efficient and effective way requires appropriate and matching alternatives from the beginning. With respect

Table 8. Aspects to be considered in development phase assessment.

	Purpose and objectives	Audiences/participants clientele/scenarios	Assessment methodology and issues
Development	*Reliability security* Matching of product specifications as expressed in the concept design phase Is the system reliable enough for user testing? Compliance with applicable safety regulations. *Questions*: Do AP solutions have enough quality and safety margins to leave the laboratory and be used by real users in real scenarios?	Professionals with different expertise (from accessibility to electromagnetic experts) Recreation of different scenarios in order to subject the prototypes to situations that simulate real life	*Usual strategies*: complementation *Mixed methods*: Heuristic analysis (using real prototypes, not mock-ups), failure methods, stress tests, etc. *Issues*: – Quantitative methodologies usually totalise complementation – Technology capacity/knowledge of technologist is essential

*indicate those especially relevant for AT.

to user, it is essential to define the innovation experience as simulated, both to avoid the creation of false expectations and in case of cognitive difficulties; and we usually triangulate these techniques with traditional qualitative methodologies as focus groups or personal interviews for polishing the specific needs with quantitative methodologies as statistical surveys or short interviews to solve specific concerns.

3.3.3. *Development phase: looking for reliability*

Who/what – The development phase is mainly performed by designers and technologists that turn product specifications into a prototype, which could satisfy user expectations (Table 8). Here, the assessment is focused on checking (i) if the product has enough quality, reliability, and safety margins to leave the laboratory and be used by real users in real scenarios and (ii) if the prototype fulfils product specifications as expressed in the concept design phase. Depending on the nature of the product developed, this would also entail internal assessments of functionality, accessibility, usability, etc. In some cases, due to the criticality of the product (e.g. a fall detection device), minimum functionality should be ensured even in faulty conditions. The product should perform its required functions under stated conditions for a specified period of time and should also comply with applicable safety regulations. This has to happen in all possible scenarios of use; for example, when configuring the device, in normal use, etc. (Fuhrer et al. 2003).

How – In the development phase functional prototypes are built, and their performance as defined in the concept design stage must be assessed. We normally use different quantitative instruments that complement each other by measuring different variables related to technical performance (DeRuyter 1997; Soderberg and Lindkvist 1999; Thurlow et al. 2007). Assessments need to render operational data resulting from actual measures and should be able to be replicated.

3.3.4. *Evaluation phase: looking for contribution service*

Who/what – The evaluation phase is completely devoted to assessing product with real users in the field (Table 9). The primary objective is to determine how the product contributes to improve the quality of life for specific stakeholders. So, it should move beyond

Table 9. Aspects to be considered in evaluation phase assessment.

	Purpose and objectives	Audiences/participants clientele/scenarios	Assessment methodology and issues
Evaluation	*Contribution ,service* How product works (feasibility and reliability) with real users and in real situations How product contributes to user well-being (quality of life), acceptance, and satisfaction* Unexpected events, issues, needs, and interests in real contexts and with real users Prepare next product iterations product features that would be advisable to add, modify, or eliminate in future versions. *Questions*: Do AP solutions fit real user's characteristics (physical and psychological issues, nature of interactions and relationships, professional and institutional cultures)? What is the value of AP solutions in the light of their flexibility and adaptability to real scenarios, daily life activities, and situations?* Can we detect emergent dimensions, features, or restrictions not previously identified? (Only in final iteration evaluations – focused on the progressive construction of the product-, not in the final evaluation – focused on the validation of the final solution)	The same stakeholders taking into account in needs assessment phase (people with disabilities, elderly people, and proxies as families, caregivers, therapists, and associations), but differing in the sample size, now larger and more structured* Multidisciplinary professional team leaded by an evaluation expert	*Usual strategies*: triangulation, combination *Mixed methods*: – Aprioristic dimensions: tests, objective proofs, systemised observation scales, satisfaction surveys, statistical description processes, online quantitative record instruments – Emergent dimensions: participant observation techniques, in-depth interviews, focus groups with all stakeholders, media collection data in online social platforms, personal experiences in forums and blogs, etc. *Issues*: – As it is the first time we assess final prototypes in a real context and with real users, we must be sensitive to emergent dimensions, seising contextualised and interactive implementations with our participants and stakeholders – Having real users in real situations forces ethical and legal issues to be specially considered – Also special attention to management of user expectations – Technology learning processes might be required

*indicate those especially relevant for AT.

'working' and 'goods' towards 'contribution' and 'service'; from merit based to based on value criteria. Other objective is to validate technology-enhanced performance and evaluate developmental implementation. We want to contrast, compare, and actualise designed and developed technological solutions in order to validate previous decisions about the product; to evaluate unexpected events, issues and interests; and to be open to emergent new uses, developmental issues, conditions, possibilities, and potentialities. In the AP context, we must pay special attention ensuring problems and weaknesses that assessments detect are not due to the lack of know-how of operational procedures. Thus, if participants are interacting with the latest technology, they may need parallel learning processes about how to use it; we have to take especially into account that the technology gap is especially evident in some populations as people with cognitive disabilities or elder (Pohlmeyer et al. 2009; Batchelor and Bobrowicz 2014). The particular assistive context demands engaging end-users and other stakeholders (caregivers, educators, therapists, associations, etc.) in making possible 'expansive learning cycles' for knowing a prototype's possibilities and correct usage.

How – In the evaluation phase, we will usually choose a *combination* strategy, integrating the assessment of aprioristic and emergent dimensions to tune instruments used to

Table 10. Project organisation chart.

		Work packages			
		Needs	Design	Development	Evaluation
	Coordinators	*Research centre*	*University A*	*Company A*	*Hospital*
Groups EG	*University A*	University A + patient association a	University A	University A + company A	University A + patient association a
CG1	*Research centre*	Research centre + patient association b	Research centre	Company A	Patient association b
CG2	*Hospital*	Hospital	Company B	University B + company C	Hospital

Notes: Project coordinator – Company A; technical coordinator – University A; methodological coordinator – University A.

validate, give credit, and evidence decisions made in previous phases. The combination can be done using tests, objective proofs, systemised observation scales, satisfaction surveys, statistical description processes, and with online quantitative record instruments, together with participant observation techniques, in-depth interviews, focus groups with all stakeholders, media collection data in online social platforms, personal experiences in forums and blogs, etc.

4. Case study

4.1. Implementation

Xassess comes from the co-work and viewpoints of three different and complementary disciplines (design, technology, and sociology) represented by the authors' backgrounds. We iterated the protocol and tools in several AP projects along many years, until reach the optimal cross-disciplinary assessment methodology, here presented. It was finally tested in three different scenarios with transdisciplinary teams from the healthcare sector, academia, and private companies.

These scenarios were framed into a paradigmatic project where, along 40 months and four iterations (see Figure 2), we developed three parallel online social network (OSN) for tele-assistance, tele-rehabilitation, motivation, and social-activation of people (and their social environments) with neurodegenerative and chronic illnesses (Parkinson, Alzheimer, and brain damage). There were two big challenges: the existence of multiple user profiles (with and without special needs) using the OSN that demanded different assessment strategies; and the complex multidisciplinary (design, software development, healthcare, social care, and business professional profiles), multipartner (seven partners), and transregional (four different regions in Spain) consortium that demanded different operating methods to share objectives and understanding between professionals. Table 10 shows the project complexity in multidisciplinarity and management levels; authors leaded University A as technical and methodological project coordinators and as Parkinson's group coordinators. We divided these scenarios into two groups: experimental (EG) and control (CG1 and CG2), each corresponding to a particular disease. Carrying out in parallel, they served us to validate the tool in scenarios of identical conditions of time, budget, team, and general objectives of the project. Partners' profiles were the same in each scenario, but the assessment methodological management was different. Regarding specific professionals, while end-user representatives and designers were different in each scenario, there was a unique team of software developers that implemented the solutions. Xassess was only applied in

the EG, while in each CG a suitable mixed method assessment was designed and developed independently by expert evaluators. Considering patients, relatives, carers, and therapists, a sum of 60 end users participated in different phases of the project, out of which 21 were related to EG, 18 to CG1 and 21 to CG2.

4.2. Results

Table 11 shows how project's assessment has been implemented according to Xassess; main associated results; and a discussion about them that reflects the analysis of methodological differences between CGs and EG, and how these differences affected the product, the design management, and the way in which each project concluded.

4.3. Discussion

Innovative AP design and development can run in a wide variety of frameworks, depending on the financing entity (public body, private company, or user association), project partners (university, research centres, companies, etc.), product or service scope (concept validation, prototype, commercial product, new design, or redesign), budget, resources, and time range. Specific assessment methodology and outcomes depend on each project's strategy, usually seeking to determine the impact of the AP to be created. In fact, evaluation is one of the challenges we have to deal with in the AP's field; but it's not the only one. In the following we summarise the main facts in the complex AP design context:

- *Challenging field research*. Sometimes derived from economic and/or time restrictions (user sample is reduced making it difficult to have statistical significance), sometimes because of the nature of the research (too intrusive and too difficult to isolate research variables), putting assessments adequately into the field can be complicated.
- *Difficulty to design comprehensive and strategic evaluations in all phases of the project.* Diversity of methodological approaches between partner's profiles (technical, sociological, design, etc.) forces project steering to set common methodologies. Sometimes this is not well received by all partners, making it necessary to overcome the resistance to change. Derived from this, evaluation objectives are sometimes not shared by all members of the project team, resulting in different outcomes sometimes useless for the project objectives.
- *Limited significance of quantitative outcomes in AP context.* If having enough budget and time, it is easy to get a lot of data, extracting conclusions with statistical significance; nevertheless, they are likely to differ from the reality perceived. This poses a problem for one-dimensional approaches and constitutes the great advantage of mixed methods as it allows refining, qualifying, and significantly enriching the interpretations; said interpretation divergence becomes complementarity.
- *Limited openness to subjective data and qualitative methodologies.* Although, due to their interpretative nature, qualitative methods are naturally closer to design practice (Swann 2002), quantitative methodologies are more established in technological contexts. Derived from our scientific/technical vision, data and statistics are essential to prove the value of technology as well as the rigour of our evaluation. Of course, we need objective data but assessment with end users must be open to include subjective data as an outcome; in fact, not considering qualitative information in engineering design

Table 11. Needs assessment, concept design, development, and final evaluation comparative.

	EG methodology	CG differences	Results
Needs assessment	*Strategies, techniques and instruments*: 1. First exploration through *surveys* for three different types of users (professionals, caregivers/relatives, and patients), focusing on *perceived*, *common*, and *derived* needs 2. *Combination* with *focus groups* for each collective, going deeper into *suspected*, *specific*, and *transversal* or *interactive* needs 3. Second *combination* (only in EG) with an ethnographic technique based in *video self-recording*, aimed to explore the emotional user universe and some taboos that didn't come up in the previous activities 4. Third combination an ad hoc designed collaborative personas, saturating identification of needs, and *combining* with another new methodology, Relational Needs, also designed by us to found a new perspective about *transversal needs* 5. Conclusion with user *needs prioritisation.* Derived from the project's heterogeneity of the user profiles and related stakeholders we concentrated on determine those more relevant and identify similarities among scenarios and profiles *Users:* Full sample of patients, relatives and professionals (caregivers and therapists) *Team:* Multidisciplinary team from the project consortium, composed by professionals involved in design, development, and evaluation. Leaded by evaluation and design experts	*Strategies, techniques and instruments*: Techniques and instruments of points 1, 2, and 5 were applied in both CGs. Nonetheless, the main strategy was complementation without a reflection about the strategy of applying them. Later, advised by EG, both CGs performed point 4 in order to fill some gaps detected Needs classification were formulated only from a thematic point of view. The possibility that some sensitive issues might have been overlooked was not considered. So point 3 was not applied *Users*: no differences *Team*: In CG1, development team did not participate in needs assessment phase In CG2, design team did not participate in needs assessment phase, and the Personas method (point 4) was not applied there	In EG a balance was achieved between the two overall assessment objectives: *Knowledge Empathy*: The knowledge component was well focused on the development of the particular product to be designed In both CGs those balance was not as accomplished Furthermore, results leaned towards the main stakeholder expertise of each evaluation. Full information about global issues every disease was obtained, but the ultimate goal was blurred, that it is to obtain the relevant information to design the specific product: the OSN. In fact, a considerable part of the outcomes in both CGs were never used. We could say that CGs obtained lots of data but little information and EG obtained much more useful information; as Clevenger, Haymaker, and Ehrich (2013) state: 'more data does not always help the designer' As a result, in following iterations, the EG need assessment strategy was mainly focused on outlining specific issues or emerging points. This, besides requiring much less effort and resources than CGs, that needed to complete cycles of needs assessment, also prevented a certain burnout of users and teams

Concept design	*Strategies, techniques and instruments*: 1. Low and high-fidelity prototypes, assessed by *cognitive walkthrough complemented* with quantitative instruments as *structured observation scales* and *checklist indicators*. Both with academic experts and design professionals 2. *Wizard of Oz* technique to assess usability issues *combined* with in-depth *discussions* (health professionals and end users) to assess dissonances between user perspectives and the ideated product concepts 3. A *little inquiry* about user satisfaction to preview the grade of acceptance of the specifics designs *Users*: Full sample of professionals. Small selected sample of each range of patients and relatives *Team*: Multidisciplinary team from the project consortium, composed by professionals involved in design, development, and evaluation. Leaded by a design expert	*Strategies, techniques and instruments*: CGs strategy was complementation of techniques instead of combination *Users*: no difference *Team*: In CG1, development team do not participate in concept design assessment In CG2, design team participate only in design, not in the assessments of this phase	Because of the better performance in needs phase, designs in EG were more suitable and balanced to engage each user profile. User-fit feasibility and user satisfaction were also better EG could maintain the same concept design along the rest of iterations. On the contrary, CG2 had to change its design in the subsequent iterations, finally adopting the one developed in the EG, with some changes to fit the peculiarities of the new scenario. Meanwhile, CG1 encountered more problems than the other groups in development phase Again, early investment in a proper assessment plan results in a saving of resources over the medium and long term
Development	*Strategies, techniques and instruments*: *Complementation* of heuristic reviews with *stress tests* that characterised the stability of the system. Programmers simulated multiple user-multiple access- multiple actions with the platform during 2 weeks in order to check system reliability *Users*: No users participated in this phase *Team*: Developers team	*Strategies, techniques and instruments*: As far as assessment methodology, there were no differences among CG and EG. Nonetheless, the object of the assessment varied, due to the different levels of objectives achievement in each group *Users*: No users participated in this phase *Team*: No differences	EG developers and designers have participated in the assessment of the concept of the previous phase, so they anticipate potential technical limitations. This allow getting to development stage with some adaptations in the prototypes, ensuring the viability of its implementation in successive iterations. In the process of adaptation of the prototypes, prioritisation of needs and Xassess tables are used as tools of communication, negotiation and agreement between developers and designers On the other hand, developers in CGs are not present to predict and warn about the unfeasibility of proposed designs. At the beginning, this provoked mismatch between design evolution and project advance and finally it resulted in CG1 abandoning its development and adopting EG's solution.

(*Continued*)

Table 11. Continued.

EG methodology	CG differences	Results
Evaluation *Strategies, techniques and instruments*: Final evaluation was based and structured in the first project step, when we established objectives and indicators, according with Table 5. Specifically, we define four assessment objectives: Acceptance of the OSN by users; Productivity improvement; Quality of Service Improvement; and Fostering of social relations *Users*: The same stakeholders participating in needs assessment phase (people with disabilities, elderly people, and proxies as families, caregivers, therapists, and associations), but differing in the sample size, now larger and more structured *Team*: Multidisciplinary team from design, computer science, and evaluation leaded by an evaluation expert. In the last evaluation iteration, only evaluation experts supported by developers in the quantitative data gathering and analysis	*Strategies, techniques and instruments*: Both CGs reused complementation strategies they were used to in other projects. Instruments are mostly quantitative *Users*: no differences *Team*: In CG1 only social team participated in assessment definition In CG2 technological and social teams participated assessment definition	CG first draft proposals contained, as needs assessment planning, some assessment dimensions (e.g. CG2 proposed EuroQoL-5D) that did not concern project and product objectives, and left out some important dimensions Finally, EG assessment planning for final iteration (see Table 11) was adopted for both CGs, changing only inclusion and exclusion criteria about recruiting participants. CG2 had adopted yet EG design, so assessment adaptation was direct. CG1 kept its design, but had to renounce implementing several functionalities and carried out a reduced version of EG assessment plan

usually leads to suboptimal solutions (Chen and Lee 1993).*Maturity and innovation of developed products and services.* Special conditions of users, together with the finishing of the prototypes assessed, hinder (and sometimes impede) the process. If concepts are also too new compared with current approaches, product comprehension might also make assessment difficult.

- *Time and economic restrictions.* Limited time and budget are key constraints in design practice (Goodman-Deane, Langdon, and Clarkson 2010; Cardoso and Clarkson 2012); evaluation as a part of the process must be framed into a project's duration and resources. Additionally, literature usually classifies AP users as novice when having less than six months of experience (Arthanat et al. 2007). As a result, the evaluation methodology put into place may not be best suited to the characteristics of the user and/or product, but the most convenient given the conditions of the project.
- *Assessment experts with required transdisciplinarity are not a common professional profile in teams.* As a result, usually user representatives working in the project with deep user knowledge (care givers and health/social professionals) but with backgrounds lacking in assessment methodology, may play this role deficiently.

From this reality, the tool progression was shaped in various levels, from some agreements and guidelines about what to take into account in the assessment process and about the need to combine strategically quantitative and qualitative methods; to include later the awareness of the need to go beyond multidisciplinarity and its difficulty; and to finally design a tool to manage the transdisciplinarity. Designer figure implication also evolved along the process, from being one piece in the gear to finally turn into a leading figure present in all phases of project, since assessment is understood as a design tool.

After applying the complete tool, the improvement is obvious with respect to previous projects, in the effective use of all the assets and capabilities; in improvement of team communication; and in the quality of solutions (user satisfaction, user-fit, and effective use of the product). The experimentation here presented additionally provides evidence in identical scenarios, with same project methodology, time, budget, professionals, objectives, product and users' profiles. Additionally, Xassess demonstrates to be appropriate in order to improve project management and effective use of resources that is not only applicable in AP but in any multidisciplinary design environment. Xassess is conceived on basics easily adaptable to any context:

- Assessment should be systematically considered from the beginning of the project and interweaved at every stage; not just as the final phase of the process in order to validate the prototypes developed.
- The evaluative topic is not just a technological object, it becomes an interactive process involving people (social activity, emotional issues) and aiming for their subjective well-being; thus, it is necessary to include qualitative methodological approaches.
- Assessment needs per definition the involvement of end users and this is always a challenging issue (Goodman-Deane, Langdon, and Clarkson 2010). A designer with experience inclusive design and an assessment methodology expert (or an individual who have design and assessment transversal training) must leader this process, being the user experts in charge of providing valuable feedback to the project. Designer empowerment has emerged both as a consequence and as a driver of the change.

- Methodological implications need to be considered, and field research (users, tools, involved disciplines, context, and time) adequate to project expectations and resources. Thus, implementation of a quality assessment implies changes in methods, not only in the tools and methodologies, but also at the project management level.

Specifically, the instruments here proposed proved their usefulness in real projects at several levels:

- A guide to facilitate the project management of assessment activities.
- A checklist to define assessment indicators at the beginning of the project.
- A source of inspiration in the conceptual phases of the product.
- A checklist to define product requirements and specifications.
- A checklist to facilitate the process of decision-making in the design process.
- A tool to facilitate the process of decision-making in the project.
- An internal communication tool between multidisciplinary teams, in order to keep common goals and shared understanding between disciplines.
- An external communication tool between project team and users, easing the needs prioritisation, objects settings among others.
- An agreement tool for teams, to discuss different points of view or to solve misunderstandings about agreements taken months ago.

5. Conclusions

Since AP design seeks progressive adaptation for the well-being of end users, we need an open attitude towards building objectives and defining technical specifications and, second, a control attitude for validating them. Thus, the design process must be formulated while articulating the assessment all along each project stages, and enabling consideration of the assessment as a constitutive part of the design process itself.

Derived from a large interdisciplinary (social, educational, economic, design, and technical development) experience in product design projects, we studied why, how, what, when, and who need to assess in the project, creating Xassess, a set of instruments that proved their usefulness in real projects at several levels.

We also identify a number of lessons learned regarding assessments in the processes involved:

Assessment in AP design is a singular (different from other mainstreaming products) process that evaluates complex dimensions and demands in a multi-referential and cross-disciplinary work. Hence, it is very important to deal with several considerations about evaluation dimensions character: (i) their *complexity* (What does improving quality of life mean? Are we able to measure the quality of life? What do involved people understand by this notion?); (ii) their *interactive* nature, derived from the product contextualisation in real use and in real life; (iii) their demand of a *translation model of innovation* (If an AP creates new realities in people's lives, what do we assess? How does an AP respond to the needs that people already have, or how does an AP create new needs and other lifestyles?).

Assessment is carried out in a conflict of stakeholders' interests that have to be dealt with a negotiated and dialogical assessment approach. An AP integrates multiple stakeholders with different needs and interests (end users and relatives, caregiver, and end-user associations,

public bodies and official institutions, researchers, developers, and industrial stakeholders) that are necessary to bring the AP to reality. The evaluation focus will be relied upon for their different motivations and interests, but it is vital to not lose focus of its primary objective: user well-being, something that should be considered by all stakeholders. Xassess, focused on the co-design and co-creation of technological solutions into a socio-constructivist perspective of the evaluation processes, is particularly sensitive to this conflict.

Assessment is carried out also in a conflict of interests of the disciplines or departments involved in the project, which have to be dealt also with a negotiated and dialogical assessment approach. Social professionals, designers and developers have their own object worlds that imply different assessment visions. The establishment of a common ground and the strengthening and facilitation of the shared understanding among disciplines is essential to ensuring real success of the assessment plan. Our principal contribution is to build a model scientifically robust enough to carry out transdisciplinary assessments. Xassess have demonstrated to be of help as an internal communication tool, as checklists to facilitate management of the assessment, to define indicators, requirements, and specifications, to facilitate the process of decision-making, and as a source of inspiration.

Assistive product design needs a systematic and adaptable method of evaluating each product for particular end-users and situations. This premise is especially important when we want to tackle the impact in the user's quality of life using an AP. For instance, we can know if a solution 'works', but we might not appreciate how they 'contribute' to the improvement of user's well-being and other stakeholders' needs and motivations. Assessment requires a consolidated methodological construction, evidencing the need for appropriate tools and a systematic method of evaluating each product for a particular end-user motivation. Xassess is adaptable enough to enable the design of assessment strategies that allow not only scientific evaluation but also connection with the user in a sensitive and revealing way. The answer is the combination of (i) building the most suitable model to project strategy (depending on the user, determination of the product and well-being conception);
(ii) user flexibility to adapt to the emerging project changes; (iii) the evaluator capacity to create a necessary propitious ambient that facilitates user motivation and an atmosphere of trust; (iv) and the project manager capacity to create a propitious ambient that facilitates team awareness of sharing objectives relevance and of participating in assessment proactively.

A general and systematic method of evaluation demands an integrated methodological approach. We are managing assistive concepts that run the risk of being directly translated into certain methodological preferences (justification and demonstration imperatives), responding to a specific tradition of science (objective and quantitative) and therefore using measuring tools as unique representational solutions. As we need to open our evaluation to suit to situations in life, not be restricted aprioristic goals, be open to emergent issues, etc. we cannot be confined to methodological limitations.

The case examined in this paper, involved along 4 years 3 subprojects, 60 users, 7 partners, and 30 professionals with multidisciplinary profiles, demonstrate that our methodological, Xassess, contributes not only to achieve better results in the design of AP products, but also to optimise the global process of managing the design of AP. In any case, we encourage using Xassess either as evaluation design and management guide, as training material for professionals not habituated, as communication tool among teams, and even as a design guide for AP and design for all products.

Notes

1. Assistive products (AP) are usually referred to in the assistive field as assistive technology (AT) as any product, service or system aiming to increase, maintain, or improve the quality of life of people with special needs. As the objective of the design does not necessarily have to be technological, we find the term 'product' more appropriate than 'technology'.
2. From 'Good design enables, bad design disables', slogan coined in 1993 by Paul Hogan, founder of the European Institute for Design and Disability (EIDD – Design for All Europe).

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ORCiD

Teresa Blanco http://orcid.org/0000-0002-1831-3342
Alfredo Berbegal http://orcid.org/0000-0003-0972-7831
Rubén Blasco http://orcid.org/0000-0003-2286-9762
Roberto Casas http://orcid.org/0000-0001-5316-8171

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