APPLYING A COMBINED USER-CENTRED DESIGN APPROACH TO ASSISTIVE SHOPPING TROLLEY DEVELOPMENT IN DESIGN EDUCATION

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Abstract

In the field of Ambient Assisted Living, the present research proposes a combined User-Centred Design approach that exploits the strengths of systematic and participatory design methodologies with the final aim to design an assistive device to solve mobility problems of elderly people in crowded environments. The application of the approach allows research to investigate which information gathering technique is more effective for this context of use and to find out competitive AAL solutions for specific target users. The experimentation is carried out by students attending an industrial design course. An experimental protocol is arranged to compare the outcomes from the different stages of the approach application. The scientific contribution of the present work regards both the presented results, that confirm how much effective is ethnography in respect to role-playing and traditional desk research in case of products oriented to special target users, and the educational experiences in the field of AAL.

Keywords: Design education, User centred design, Evaluation, Ambient Assisted Living, Requirement gathering

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1 INTRODUCTION

The design of products/services for Ambient Assisted Living (AAL) is one of the most strategic challenges in healthy life due to the needs of aging population and the technological advances in enabling low-cost devices (Lattanzio et al., 2014). The success of such systems strongly depends on the designer ability to gather information about the customer needs (e.g. personal characteristics, believes, attitudes, preferences) and contextual barriers and to translate them into satisfactory product features (Bevilacqua et al., 2013; Goldhaber at al., 2012). However, most traditional design approaches have been accused of failing to engage with users in the design process: compromising commercial opportunity and the interactional experience of users (Wilkinson et al., 2014). The present research starts with the aim to verify this statement by exploring the effects of different user understanding techniques on traditional design carried out by students in Industrial Design.
A combined design approach that exploits the strengths of systematic engineering design (i.e. structural and logical procedure and functional modelling) and the benefits of some information gathering techniques coming from most User-Centred Design (UCD) approaches, is applied to the generation of new ideas to develop a shopping aid for older people. The application goal is to investigate if the introduction of these information-gathering techniques is useful to achieve an increased product quality. Simultaneously, teaching this approach allows industrial and mechanical engineering students to be better to sensitized toward less-able bodied user needs without leaving procedural methodologies. These research goals are achieved by introducing three techniques for collecting customer needs, wishes and preferences that are respectively desk research, ethnography analysis and role-playing in traditional systematic engineering design and by applying an experimental evaluation protocol to measure their effects on the definition of user requirements, functional models and design concepts. The use case is represented by the design of an assistive device to solve mobility problems of elderly people in crowded environments, e.g. shopping centres. It is well known that elderly have strong difficulties in moving in outdoor spaces: consequently, they prefer to stay at home, but in this way they gradually lose contact with society, which is extremely dangerous for a premature aging of mind and body (Cattan et al., 2005). The design is conducted by students attending an Industrial Design course and enrolled in the last year of a Master of Mechanical Engineering. As the course lasts four months the analysis cannot take into consideration other stakeholders needs as suggested by most systematic design and UCD approaches.
The scientific contribution of the present work regards the achieved results and the educational experience in AAL. Experimentations confirm how much effective is ethnography in respect to role-playing in case of products oriented to special target users, and demonstrates that requirements and functional models are affected by the technique used to collect information.

2 RESEARCH BACKGROUND

2.1 Older people as technology users: needs to address

It is worth to notice that in AAL the analysis of user demands and aspirations and the identification of proper design requirements are fundamental to conceive usable and acceptable solutions. In the field of gerontology, the Roper-Logan-Tierney model of nursing is often used to understand the needs of elderly people and to investigate the main Activities of Living (ALs) that can be supported by technological artefacts (Roper et al., 2000). While Maslow analyses the “basic needs” (Maslow, 1943), Roper’s model allows the identification of objective and observable activities to be directly measured and to shift from a human motivation level to a technological one. The identified ALs are: Maintaining a safe environment, Communicating, Breathing, Eating and Drinking, Eliminating, Personal cleansing and dressing, Controlling body temperature, Mobilising, Working and playing, Expressing sexuality, Sleeping, Dying (Roper et al., 2000). In addition, to understand the individuality of each person, it is necessary to take into account also the interactions of the ALs with transversal contents that shifts user needs analysis from a functional level to a socio-cultural-psychological one: lifespan, dependence/independence continuum, and factors influencing the ALs. There are considerably changes when moving along the lifespan where the continuum goes from dependence to independence due to the influence of biological, socio-cultural, environmental and politico-economic circumstances. The analysis of ALs and the above-mentioned transversal needs give a strong background to the technical development of any technology/product/service: independence, ageing, needs and resources

are indistinguishable concepts that cannot be treated separately.
Even if most solutions and services are conceived to offer an effective support to these target users, the application of technological innovations is still limited due to the difficulties to assess user wishes and preferences at the beginning of the design process. Numerous studies recognize their crucial role for technological solution identification and decision-making (Scherer, 1994; Venkatesh at al., 2003; Roger et al., 2011). The acceptability of technology actually seems to be strictly connected with the users' believes, personality, attitudes as extensively described in the literature (Svendsen et al., 2013; Bradley et al. 2013). On a methodological point view, it can be assumed that the design strategies that required more contact with the final users allow designers to draw up the aspects not directly inferable by the evaluation of the needs, but that determine the market success of the assistive technologies.

2.2 How to translate elderly needs into novel solutions: UCD principles

UCD represents a valuable mean to overcome the above-mentioned challenges in enabling technology design, and make older people aware of the potentialities of modern solutions. Extensively defined in literature (Roger et al., 2011), UCD is conceived both as a philosophy and a corpus of methods based on the assumption that a technological artefact has no reason to be developed if nobody would like to use it. Shan and Robinson (2006) emphasise that gathering users' needs, preferences and wishes has been shown to determine both the success/failure of the development of technology and the quality associated to the product. For this reason, UCD promotes a close involvement of end-users and stakeholders through interactive cycles of concept, design and prototyping, testing and trials and deployment (Shah and Robinson, 2006). Different methods can be used to achieve useful knowledge on user requirements at every stage of the process as reported in Table 1.

Table 1. Methods for technological and user requirements (from Shah and Robinson, 2006)

Concept stage	**Design stage**	**Tests and trials stages**	**Deployment stage**
Interviews Usability tests + Questionnaire surveys + User and producer seminars Task analysis + Discussion + Observations Simulations of the users' feedback	Interviews Usability tests + Questionnaire surveys + User and producer seminars Task analysis + Discussion + Observations Simulations Human factors approach Design sessions	Interviews Usability tests + Questionnaire surveys + User and producer seminars Task analysis Video recording + Observations Simulations Human factors approach	Interviews Usability tests + Questionnaire surveys + User and producer seminars Use experiment Video recording Focus groups (Delphi method)

For the purposes of the present research, three different strategies for data gathering have been selected. They actually request different levels of contact and immersion into the users' perspective. They are as follows:

- *Desk Research:* it is intended the activity of analysing the sources available in literature and/or published on the Internet, about the topic of interest without any direct contact with sample users.
- *Role-playing:* it is defined as "the practice of group physical and spatial pretend where individuals deliberately assume a character role in a constructed scene with, or without, props" (Simsarian, 2003). In particular, two key features of role playing are outlined: "being in the moment" that allows a vivid and focused exploration of situations, and "physicalization" that consists of using the entire body to explore the generation of ideas in order to take "brainstorming" to "bodystorming". In this context, the use of Personas is a useful support to role-playing, due to the opportunity to follow a script representing consumers, based on a predefined set of user characteristics. Personas are descriptions of fictitious users derived from on

qualitative and/or quantitative data. They can help designers in feeling in touch with users and sharing a common understanding with the team members (Nielsen, 2012).

- *Ethnographic* methods: the main tool of ethnography is observation. Observing users in the real context is often the best way to determine users' needs and wishes. Even this method allows a significant collection of a useful plethora of data; it is not so widely adopted by designers because of time-consuming (Ventura, 2013; Bichard, J. et al. 2010). Taking pictures and notes according to a pre-defined checklist for guiding the observation is the preferred mode to perform observation.
  In addition, interactive ad-hoc interviews can support the understanding of user needs.

2.3 Traditional systematic design: limits for AAL solutions

In mechanical and industrial design, most technical products are the result of the application of systematic engineering approaches that are generally problem-oriented, procedural and structured to facilitate the application of known solutions to related tasks. Most are focused on form-function relationships to find feasible solutions. All approaches have in common the fundament that each product, represented as a system, exchanges input/output data with the environment and the relationships between these flows determine the implemented functions (Pahl and Beiz, 1994; Otto and Wood, 2001). The main recognized steps of the systematic procedure are as follows:

1. Clarification of tasks that implies the collection of information about basic, technical and attractive requirements to be embodied in the solution. Requirements are structured into a checklist where demands and wishes usually derive from questionnaires submitted to consumers and outcomes from desk research focusing on market situation analysis, trend studies and known requirements;
2. Conceptual design that involves the definition of the functional model and the search for suitable solution principles;
3. Embodiment design to determine system layout and forms of assemblies and components;
4. Detail design that aims to define the arrangement, dimensions and surface properties of individual components and to produce all drawings and documents for manufacturing.

Focusing on the first specification stage, a critical issue seems to be a lack of structured methods to capture and elaborate data on user needs. This aspect has meaningful effects in case of products/services oriented to special target users (e.g. elderly, disabled people, children) as demonstrated in sections 2.1 and 2.2. For instance, Pahl & Beiz (1994) did not mention any user involvement in the first conceptual design stage. The list of requirements is the result of the designer's ability to infer useful information from the market, the context of use and literature overview. Specifically, they claimed that his/her professional knowledge "is needed particularly for the drawing up of specifications". Otto and Wood (2001) focused more on product specifications than on customer needs' elicitation. They suggested the designer to collect enough information from the customer voice and other sources (e.g. different stakeholders' demands, market analysis, literature overview) to produce a specific set of needs, without specifying how this process is conducted. Moreover they claimed that customers do not often perceive some aspects or express some needs that are fundamental to be included in specifications. The House of Quality (HoQ) methodology (Ullman 1992) represents a way to translate customer needs into design specifications and assure that customer needs drive the development process. However most literature on HoQ states that the requirement list derives from a deductive analysis by designers considering internal (i.e. company) and external (i.e. customers, market) needs. Also looking at systematic design with a focus on human factors, Rosenblad-Wallin (1985) did not consider any customer involvement at the specification stage where the designer has to analyze the design problem on the basis of his/her expertise, use situation knowledge and skill.
As a consequence, the introduction of proper methodologies to drive user information gathering appears to be useful to improve the systematic procedures at the specification stage.

3 RESEARCH APPROACH

3.1 The combined approach for conceptual product design

The research work is based on a combined approach that introduce some UCD principles in systematic engineering design with the purpose to improve design efficiency and quality of human-centric products, like assistive products and AAL devices. It is structured in three main phases as follows:

I. Product design planning
   1. User analysis by A (desk research), B (ethnography) or C (role-playing)
   2. Definition of the user needs, including demands and aspirations and relative weights
   3. Identification of the user barriers
   4. Requirements elicitation (basic, technical and attractive requirements)
   5. Clarification of user tasks
   6. Neutral formulation of the design problem

II. Competitive analysis
   1. Market analysis (to select competitive products)
   2. Definition of the House of Quality (step 1)

III. Conceptual design
   1. Functional modelling (definition of functions and main functional modules)
   2. Concept definition (product layout and design of all components)

The subsequent stages (i.e. embodiment and detail design according to Pahl and Beiz, 1994 and Otto and Wood, 2001) are not included in the approach as their aim is to develop a solution when it has been yet selected. The overall approach is characterized by iterative cycles of problem formulation (i.e. task clarification and requirement specification), synthesis (search for solution), representation, evaluation and decision as literature on design methods requests. Iterations end once the concept has met the user requirements fixed in stage I.

The expected output of the phase I is presented in Table 2. The first column contains the elicitation and classification of user needs, demands and wishes (generally called "needs" for simplicity). Classification is based not only on their presence/absence but also on users' expectation in relation to the categories presented in Sixsmith et al. (2011) (i.e. *Social interaction and communication*, *In/outdoor mobility*, *Accessibility*, *Environmental/personal safety and security*). The second column presents the barriers users experience in actual contexts of use. It derives from the analysis of the interaction between users and environment. The third column is an elaboration of needs and barriers in terms of basic, technical and attractive requirements according to Pahl and Beitz (1994). The last three columns are useful to build the functional model. In this case tasks are not refereed to system tasks as systematic engineering suggests but to what the user does with the system to meet their needs and overcome his/her experienced environmental barriers.

The output of phase II is the House of Quality matrix that makes measurable and comparable different competitive products by correlating user needs and technical/attractive requirements and translating them into engineering design targets (Akao, 2004). It correlates user requirements with product specifications in order to benchmark competitors and identify weaknesses and strengths of available solutions.

Phase III results consist both of schemas containing the functional structures representing the overall product function at the bottom level and its decomposition into sub-functions at the lower level and of drawings, sketches and in some case of 3D models of the solution principles.

Table 2. Outputs of phase I

Needs & Weights	Barriers	Requirements	Tasks	Functions	Flows
What users need and expect according to the design goal and its relative importance	*What users are afraid of in the product context of use*	*How the product idea satisfies the identified user needs and support users to carry out specific tasks*	*What users can do thanks to the new product to satisfy explicit and implicit needs*	*What the product does (verbs)*	*How functions are connected - dependencies among functions (nouns)*

3.2 The evaluation protocol to assess design outcomes

An experimental evaluation protocol is defined to demonstrate the assumption that if a designer adopts different techniques to capture user information, the following activities are affected by the results of the preliminary analysis and the design outputs differ.
The evaluation protocol considers the main outputs of the design process, from user analysis to the product concept definition. In order to determine the quality of those outputs and measure them in a structured way, a set of evaluation metrics are set. All proposed metrics are listed in Table 3 with the corresponding measurement indicators.

Table 3. Evaluation metrics to compare design outputs

Cat.	Dim.	Metrics	Measurement modality	Meas. unit
User information gathering	*Effectiveness*	*Needs fulfilment*	*Analysis of the needs fulfilment based on the Soprano's study*	*Ratio*
		Balance between B-T-A requirements*	*Analysis of the deviation among the ratio between the number of requirements (basic, technical and attractive) and the total number of requirements*	*Deviation (0<Δ<1)*
	Quality	*Requirements originality*	*Analysis of the requirements list originality*	*1-5 Judge*
		Designer transfer ability	*Analysis of identified correlations between Needs, Barriers and Tasks*	*1-5 Judge*
Function Definition	*Effectiveness*	*Multi-Functionality*	*Analysis of functional decomposition (no. primary / auxiliary functions, no. sub-functions) and integration (flows no. and variety)*	*1-5 Judge*
Product concepts	*Effectiveness*	*Embodied functions*	*Fulfilment of functions by technical solutions and coherence between functions and solutions*	*No. (0<N<1)*
		Supposed Ergonomics	*Assessment of the level of usability and ergonomics that the solution could have*	*1-5 Judge*
	Quality	*Style of the concept*	*Analysis of pleasantness, attractiveness and recognisability of the product concept*	*1-5 Judge*
		Technical feasibility	*Feasibility of the solution from a technical and productive point of view (clear, simple and safe)*	*1-5 Judge*

** B = Basic, T = Technical, A = Attractive*

Metrics refer to the evaluation of three main items: user information gathering, functional model, and developed product concepts. Metrics measure both effectiveness and quality of the achieved outputs. For instance, ratios or deviations quantify effectiveness while subjective judges expressed according to the 5-point Likert scale are used to assess the quality.
Three experts in product design carry out the evaluation of both objective and subjective metrics. Final values are expressed in terms of average results from the three involved experts.
Figure 1 sums-up the overall research approach by presenting the design approach stages on the left and the evaluation protocol metrics on the right. As highlighted by bold arrows, metrics are used only to assess outputs from stages I and III.

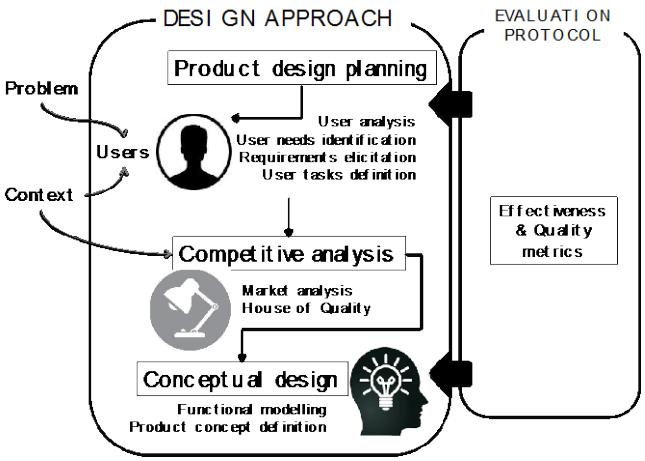

Figure 1. Research approach overview

4 EXPERIMENTAL CASE STUDY

4.1 Definition of the design problem

The experimental case study is represented by the design of an innovative assistive shopping trolley for elderly people able to support users movements in crowded spaces and facilitate product manipulation and collection. The design problem is defined on the basis of three considerations coming out from literature overview and interviews submitted to a medium-sized company producing shopping trolleys: (i) aging is usually characterized by losing confidence and familiarity with crowded public spaces such as shopping centres, supermarkets, shops, etc. (Wilkinson et al. 2014); (ii) shopping can enable people to perform exercises and maintain a good level of interaction and social inclusion (Adami et al., 2013); (iii) there are not trolleys specifically oriented to improve autonomy in mobility in shopping centres and meet elderly demands and aspirations. From a preliminary analysis some product specifications emerged that allows the designer to frame the problem and drives user needs' investigation, as follows:

1. About autonomy in mobility:
   - Physical impediments such as the reduction of visual and auditory skills, or problems at the lower and upper limbs with consequent reduced control in object manipulation;
   - Decline of cognitive abilities that affect the sense of familiarity and confidence with places and objects around them, as well as the ability of orientation and navigation;
   - Architectural barriers such as the lack of platforms and corridors, or the reduced spaces due to the presence of frames, trolleys, and prams;
   - Lack of mobility aids (e.g. crutches, canes, adjustable hangers) combined with standard trolleys or baskets.
2. About technical feasibility:
   - Eco-sustainability of materials and manufacturing processes;
   - Compliance with the International standards to assure stability, safety and high-performance;
   - Use of grip adapters and attachments in compliance with ergonomics standards and guidelines;
   - Use of easy-cleaning and antibacterial materials for surfaces in contact with the user;
   - Adoption of mechanisms to stack trolleys in case of transport and use;
   - Product manufacturing cost less than 50 Euro.

The design context is represented by crowded environments where orientation is crucial to achieve key points (e.g. exit, information point, specific sections) or to perform certain tasks (e.g. to shop, to bring a site map, to reach check-out) differing according to the context of use such as shopping centres, fairs and exhibition stands, open/closed places. In all situations users generally need a container to collect objects (e.g. food, clothes, papers) and, at the same time, some aids to avoid obstacles and move in narrow spaces. Target users are over-65 people with reduced physical and cognitive abilities. Personas have been used to represent them.

4.2 Experimental set-up

Experimentation involved 70 students attending the course of Industrial Design at Università Politecnica delle Marche. They had a general background in Mechanical Engineering, so they were not specifically prepared in product development, design theories and practices or aesthetics, but they were more concentrated on technical design. However, during the course they had been informed about engineering design methods, UCD principles and practices (e.g. inclusive design, design for all), affordances and synaesthesia principles, semiotics concepts and product design history. 30% of females and 70% of males represented the student sample. It was divided into 12 groups of 5-6 people, each representing a design team. All teams faced the same design problem and followed the proposed combined design approach. Teams differ from the adopted user needs analysis technique: 4 groups used desk research (A groups), 4 groups ethnography (B groups), and 4 groups role-playing (C groups). The design phase lasted six weeks: 2 weeks were dedicated to product design planning (from user analysis to tasks definition), 1 week to competitive analysis (market analysis and House of Quality definition), and 3 weeks to conceptual design. Time is not considered a process variable in the research evaluation since its spans are homogenous among all groups.

4.3 Experimental results and discussion

4.3.1 Outputs from user needs analysis

Every group (A, B and C) started its own design activity with the definition of the user needs and, for each of them, the identification of weights, barriers, corresponding requirements and related tasks. Groups using ethnography (B) observed people at supermarkets as well as little shops and analysed their habits and behaviours. Groups using role-playing (C) played as characters in the same environments. Both also conducted semi-structured interviews to focus on user preferences and wishes. Questions are submitted to about 10 older persons for each group in the shopping centres where observation took place or just outside them. Although questions are related to the research goal, all avoid technical terms and adopt a language that is familiar to the target users. An informed consent form is given to the interviewed to provide information about the purpose of the study and the rights of participants.

The following tables present the main results of stage I. Table 5 shows the needs and relative averaged weights identified by the three groups. The terminology is normalized to create an overall framework. It highlights the different mapping of user needs by using alternative information gathering techniques with a different level of immersion into the user scenarios and a degree of user involvement. If a group had not discovered a specific need, the relative weight is marked as "not received" (NR). The highest weights indicate the most important needs. The three columns of weights do not differ only in terms of identified needs but also in terms of needs' importance ranking.

For instance, desk research (A groups) is less effective than ethnography and role-playing because the elicited needs are less than the ones identified by groups B and C. However, its ranking is definitely more clear with weights up to 2.0. On the contrary, role-playing allowed designers to highlight more needs, but each with a lower weight value (i.e. most are below 2.0). Groups using ethnography achieved more balanced weight values and were able to define a larger set of needs.

Table 5. Needs and weights collected during experimentation (5-point scale)*

	Average weights		
Needs	**A (desk research)**	**B (ethnography)**	**C (role-playing)**
Manoeuvrability / Handling	**4,7**	**4,0**	**4,8**
Ergonomics / Ease to use	**3,0**	**3,5**	**3,7**
Support to walking / Orientation	**3,0**	**4,0**	**4,8**
Containing personal items	1,7	**2,5**	**2,8**
Support to product load-unload	**4,7**	**2,5**	**2,8**
Lightness	1,7	1,8	1,0
Adjustability / Adaptability	1,7	1,5	1,5
Comfort	2,0	**4,3**	**2,5**
Safety	**3,3**	**3,5**	**4,5**
Stability	**3,3**	**3,3**	**3,3**
Capacity	NR	1,3	1,8
Support to label reading	1,3	1,3	**2,0**
Support to shopping list	NR	0,8	NR
Sitting	1,0	1,3	1,0
Communication / Assistance	NR	0,8	0,5
Durability / Resistance	NR	1,8	**2,0**
Pleasant aesthetics	NR	0,5	**2,3**
Quietness	NR	NR	0,5
Recognisability of own trolley	NR	NR	0,3

** Average value considering all user and all groups in each category (A, B and C)*

The identified needs contain both user demands and aspirations. Examples of demands are as follows: (a) easy-to-use and handle; (b) facilitating gait, orientation and balance; (c) robust, stable and safe; (d) supporting users in grasping, handling and object releasing operations; (e) assuring protection for purchased items and personal items (bags, jackets) or any other aid; (f) adjustable in height and scalable according to the physical impediment; and (h) lightweight and easy to transport. Examples of

wishes are as follows: (a) being attractive and pleasant, (b) having a recognizable and familiar shape with vivid colours; and (c) embedding a simple and usable interface to support orientation.
Demands are used to formulate basic and technical requirements while wishes the attractive ones. Table 6 provides the requirements elicited by the groups and indicates the normalized frequency for each group category. The most relevant requirements are marked in bold as their frequency value is up to 0.04.

Table 6. Requirements elicited during experimentation

		Normalized frequency		
Type	**Requirements**	**A (desk research)**	**B (ethnography)**	**C (role-playing)**
BASIC	Stability / Anti-tipping	**0,08**	**0,06**	0,00
	Security devices	0,03	**0,04**	0,02
	Compartment for personal item	**0,08**	**0,08**	**0,06**
	Comfort / Ergonomic handle	**0,08**	**0,06**	**0,06**
	Stackability	0,03	**0,04**	0,02
	Cleanability	0,00	**0,04**	0,02
TECHNICAL	Small size (max 600x400x900mm)	**0,05**	**0,06**	**0,08**
	Limited weight (max 10-15kg)	0,03	**0,04**	0,02
	Height adjustment (±80-150mm)	**0,08**	**0,06**	**0,04**
	High volume capacity (min 50l)	0,03	**0,06**	0,02
	Efficient handling system (high quality bearings)	0,03	**0,04**	**0,04**
	Easily adjustable wheels (pivoting)	**0,08**	**0,04**	**0,08**
	Lifting system for plans	0,00	0,00	0,02
	Efficient breaking system	0,03	**0,08**	0,06
	Division into compartments	0,00	**0,06**	0,04
	Supporting / Reading system for the shopping list	**0,05**	0,02	**0,08**
	Seat / Backrest	**0,05**	0,02	**0,04**
	Lights / Reflectors	**0,05**	0,02	0,02
	High material durability	0,03	0,02	**0,08**
	Alarm / relief / assistance device	**0,05**	0,02	**0,04**
ATTRACTIVE	Original and cute design	**0,05**	0,02	0,02
	Safe design (no edges)	**0,05**	**0,04**	**0,06**
	Soft-touch materials	0,00	0,02	0,02
	Pleasantness in use	0,00	0,02	0,00
	Available in different colours	0,03	0,00	**0,04**

Once defined the requirement list and the tasks, students started with functional modelling according to Pahl and Beiz (1994) guidelines, breaking down the overall function into its sub-functions to facilitate the search for the solution principles. This search was supported by different methodologies spreading from the analysis of technical and natural systems, to the adoption of analogies, till brainstorming procedures. During this conceptual stage, that was high iterative, students create sketches and drawings to represent the design outcomes and support the team in decision-making. Figure 2 sums-up the design workflow and presents examples of outputs for each approach stage.

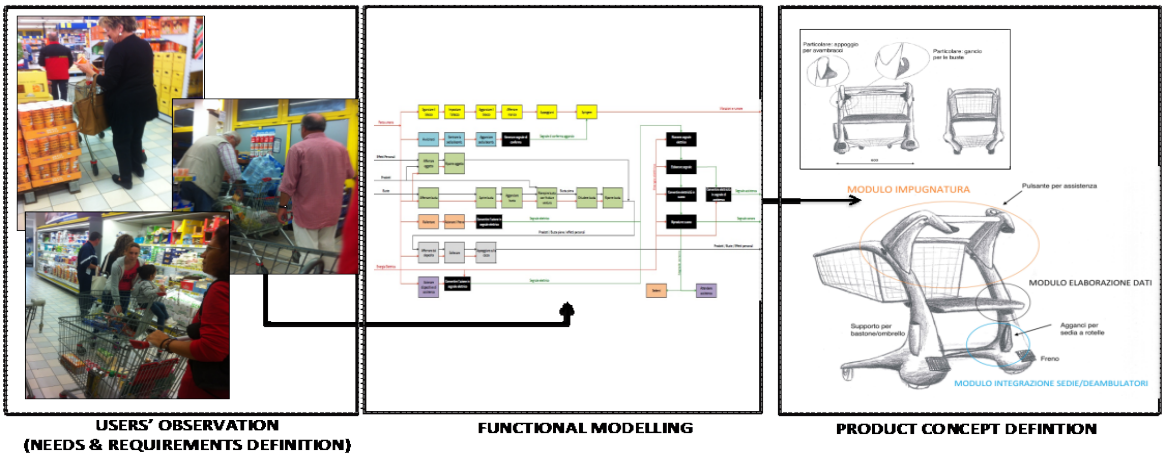

Figure 2. Examples of design outputs

4.3.2 Protocol application and discussion

Table 7 shows the results of the evaluation carried out by the three experts. The analysis focused on the first design stage about user information gathering and functions definition, which comprehends needs definition and requirements elicitation. Indeed, the research specifically investigates the impact of different user analysis on the quality of preliminary design outputs (i.e. needs, demands, requirements, product functions and relationships between functions). So the protocol analysis presented in Table 3 has been applied until function definition stage, without including product concepts evaluation.

For each group, design outputs are judged according to the protocol metrics. Then for each metric, an average value is calculated in order to consider whether and how ethnography or role-playing affects the different topics.

Table 7. Outputs evaluation for A-B-C groups

		User information gathering				**Function Definition**
		Effectiveness		**Quality**		**Effectiveness**
UCD technique	*Group ID*	*Needs fulfilment (Ratio)*	*Balance between B-T-A* requirements (0<Δ<1)*	*Requirement originality (1-5)*	*Designer Transfer Ability (1-5)*	*Multi-criteria (1-5)*
Desk Research	A1	0,50	0,20	0,40	0,80	0,60
	A2	1,00	0,20	0,40	0,80	0,60
	A3	0,75	0,20	0,75	0,60	0,75
	A4	0,75	0,40	0,80	0,60	0,80
Average results		**0,75**	**0,75**	**0,25**	**0,59**	**0,70**
Ethnography	B5	0,75	0,80	0,80	0,60	0,80
	B6	1,00	0,60	0,80	0,80	0,80
	B7	0,75	1,00	0,80	0,60	1,00
	B8	0,75	0,40	1,00	1,00	0,80
Average results		**0,81**	**0,81**	**0,70**	**0,85**	**0,75**
Role-playing	0,75	0,75	1,00	0,60	0,80	0,80
	0,75	0,75	0,60	1,00	0,80	0,60
	0,50	0,50	0,40	1,00	0,80	0,80
	0,50	0,50	0,20	0,60	0,60	0,60
Average results		**0,63**	**0,63**	**0,55**	**0,80**	**0,75**

* *B = Basic, T = Technical, A = Attractive*

From the analysis of the results, it is possible to state that generally the need ranking is quite similar among all groups. In particular, the identified needs (Table 5) are reported to the four Soprano's categories, and the relevance of such categories is analysed. They are ranked as follows: 1. Mobility, 2. Accessibility, 3. Safety and Security 4. Social Interaction. All groups gave a high value to Manoeuvrability / Handling (from 4,0 to 4,8 from Table 5) and Support to Walk / Orientation (from 3,0 to 4,8). In particular the values are higher for those groups performing role-playing (C). Contrarily, groups performing ethnography focused more on Accessibility and Comfort (4,3 from Table 5) but have a more balanced distribution of weights among all the needs demonstrated also by the needs fulfilment metric value in Table 7 (0,81 in respect with 0,75 and 0,63). However, social interaction is poorly described and needs have not been translated into requirements; as a consequence any solution provides devices to support it.
In desk research, any group had taken into account the needs declared by personas. The investigation was focused on the demands and wishes of elderly in general. Even though personas were assigned to circumscribe desk research, they were interpreted only as guidance for aged persons' study. The consequence is that the identified needs appear to be too general, superficial, inferred from prejudices and outcomes of well-known literature overviews (0,59 score of requirement originality). The analysis of proposed needs and relative ranking results in homogeneity of old population. This represents an overwhelmed vision of elderly where the dynamics of aging, its relationship with individual characteristics and a life course perspective are never faced, confirming researches of Marshall and Muller (2002). On the contrary, interviews in ethnography and role-playing have been useful to drive students in identifying which devices and tools are familiar to the elderly and are recognized as comfortable, useful and practical for the context of use. The main demand is to integrate them in the trolley of the future to overcome actual barriers. However, the fact to collect a set of artefacts to be integrated has limited students in being imaginative, creative and in finding general requirements, mainly the attractive ones (0,5 and 0,7 scores of requirements balance between Basic, Technical and Attractive).
Ethnography leads to better results in terms of function structure completeness (e.g. level of achieved abstractions, number of identified sub-functions) and integration (i.e. variety and quantity of connecting energy, material and signal flows) with a score of 0,85 in respect to 0,69 for desk research and 0,7 role-playing.
Students applying role-playing achieve worst outputs in needs definition and requirements elicitation than those applying desk research (averagely 0,63 vs 0,75), but better outputs in designer transfer ability (averagely 0,80 vs 0,59). It means that role-playing risks to realize a scarcely structured information gathering and a not well arranged set of requirements. This is the consequence of students' enjoyment and fun in assuming a character role in front of their friends. Their attention was deviated from the design tasks. On the contrary, as they made practice of the context of use and of real mobility/accessibility barriers, they have interiorized the lived experience and were able to translate the needs into successful solutions in terms of design functions (0,75 vs 0,70). This demonstrates that role-playing requires a high-level training before application instead of the other techniques and then it is more difficult to be used for educational purposes. Design transfer ability seems to be independent from the quality of the identified needs and requirements; it depends on the fact that a rigorous approach to requirements analysis leads to a good identification of the implementing functions but can limit the design creativity and innovative potentials.

5 CONCLUSIONS

The presented work presents the application results of a combined design approach exploiting different user information gathering techniques to develop assistive devices for the elderly. The study is useful both to qualify the approach to teach in industrial design courses by structuring a rigorous design methodology while making aware students on the complexity of "weak" people needs and barriers and to investigate the adequacy of data capture and elaboration methods for students and novice designers.
The main motivation of this research work is to find a novel way to inspire the promotion a user-centred technological development not only in terms of product exploitability but also mainly in terms

of quantitative measurement of the effects that a proper investigation technique can increase the knowledge of target users and improve the quality of design outcomes.
Future work will be focused on the application of advanced statistical models (e.g. ANOVA) to assess the differences among groups through the adoption, as a variance, of the user needs' analysis technique. Moreover, further studies will investigate the effects of the information gathering technique on the generation of innovative ideas and design concepts. A detail analysis of achieved solution principles is imperative. Therefore, the proposed evaluation protocol will be further detailed to assess all design outcomes.

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