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Industrial design for aircraft: models and usability for comfort in the cabin

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Abstract

This contribution introduces an innovative model of assessment and validity of the formal-dimensional-functional structure for passenger seats in economy class in the Aerospace industry. In fact in this field, the design, ergonomics and engineering determine unpublished cooperation scenarios where roles are inverted, merge and recur repeatedly, in order to establish progress in the different planning and subject areas, having a synergistic and proactive perspective.

The research activities have been developed within the framework of the research project "IMM_Interiors with Multifunctional Materials_DAC_Distretto Aerospaziale Campania" (Campania Aerospace District), in which experts from different branches of knowledge such as designers, innovative materials engineers, mechanical engineers, biologists and technical physicists from the Second University of Naples were involved. The use of new methodological dimensions resulted in the identification of common activity protocols, which were used as foundations in the planning stage, interdisciplinary and shared. The aim was to obtain a passenger seat configuration suitable to meet the demands and needs of the greatest number of individuals, according to their specifications and through the integration of innovative technologies and materials.

The impact of different cultural factors, the mixture of roles and subjects, the layering of competences and heterogeneous and contradictory operational references have contributed towards a shared narrative where knowledge and experience have established the key principles in the course of evaluation and validity (methodological-designing inclusive).

This route has allowed the acquisition of interdisciplinary skills and expertise qualified to obtain tangible results from the identification of methodological and design issues useful to optimize, innovate and strengthen the design process.

The goal was to make the acquisition of user needs systematic, through investigation and evaluation methods aimed at translating them into a structured format noted on the design process according to the principles of good design. In particular studies and research of prior art patents and thorough investigation literature regarding the state of the art of existing seat configurations and structures were carried out. Feasibility, comfort and

reliability of the existing solutions in order to analyse and evaluate each component of ergonomics, human factors (physical ergonomics), user centred design and new human factors (pleasantness of use), where characteristics and specific meanings of quality, understood as a user-seat interaction quality are preferred.

Keywords: Design, Aircraft-comfort, Ergonomics, Usability, Experiences

1. Introduction

This paper proposes an innovative model of evaluation and functional/formal arrangement validation of passenger seats in the aerospace industry, where design, ergonomics and engineering set new and unprecedented collaboration scenarios where the roles are reversed, merged, and are constantly being renewed in order to gain advancement in various fields, in a synergistic and proactive way.

The research activities have been developed within the Department of Civil Engineering, Design, Construction and Environment under a research project of IMM (Interiors con Materiali Multifunzionali) and DAC (Distretto Aerospaziale Campania) who have seen committed researchers and designers, experts in innovative materials, mechanical engineers, biologists and technical physicist.

The work is part of a research context, where the design of new structural solutions of seats to ensure ergonomics and passenger comfort by limiting the weight gain, are discussed. Based on these indications, in part imposed by the new amendments to the applicable regulations, in part by the need to ensure the necessary appeal demanded by increasingly demanding customers, which are accustomed to a high level of comfort, the research project has set itself to study solutions to meet the changing needs of aviation, without any significant impact on aircraft performance by virtue of mandatory increases in weight that could be incurred from a slavish application of solutions and materials used on large transport liner.

In particular, the aim was to systematize the acquisition of user needs, through investigation and assessment methods designed to identify needs and translate them into a structured format and verifiable within the design process according to the principles of good design. In particular the quality of interaction between the user and the seat, through the assessment of the compatibility between the product specifications, the features and the user's ability, and performance in the system in which it operates, from the functional to the perceptive-cognitive, up to the emotional aspects.

2. Usability as a model of experience and pragmatic approach

Numerous studies from the design research have shown that the functional and hedonistic characteristics of a product are two independent factors affecting the definition of the satisfaction of the consumer.

The use, possession, interaction with a product can generate different types of cognitive perceptions and emotional responses. Some products, beyond the functional correspondence, represent the conditions which define the meanings of the contexts where people live, instruments by which people construct their identity. Analyzing the subjective experience that users live through the products, or who will experience using the same, the designer interprets the experience of people as a source of inspiration and generation of solutions.

Among the most innovative approaches in cognitive psychology, for the study of the relationship between people and artifacts, the distributed cognition approach represents a new paradigm for analyzing the work, playful, and everyday activities that humans conduct through mutual relations and through the relation with the artifacts that populate the contexts in which interactions occur.

The distributed cognition paradigm asserts that the ability of human beings to carry out any activity, from the everyday ones to the more complex, depends on the distribution of all the necessary knowledge among the people, the artifacts used and the contexts where the activities take place and the interactions between these components (Rizzo 2009).

The design of usable artifacts implies considering the needs of people can quickly learn the ways of interaction, allowing them a quick execution of tasks, maintain a low error rate and help maximize user satisfaction.

The research on design and other related areas refers to the insights of these schemes. The objects, therefore, should pass on their experience, their value, should communicate information, to reflect certain uses, and are signs of a particular social status and a certain cultural level, *chairs, beyond supporting the body, also bring out the personality, the body language, and the social position* (Bürdek, 1992).

The designer then, through a product, designs not just real things, but also something immaterial, so it is absolutely necessary that the object speaks for itself. The Barthes message was that what people own is able to convey a range of meanings that are equivalent to a language, and for an object conveying the proper meaning is undoubtedly part of its function.

Jean Baudrillard, Umberto Eco and Luis Prieto developed the discourse on the functionality of the objects. Umberto Eco takes Barthes to articulate the concept of function, thanks to the use of category connotation/denotation, through which he tries to account for the primary and secondary functions of objects. Prieto reassesses the concept of function in a more rigorous way thanks to the introduction of the category working/utilities, adapting to the objects that of signifier/signified (Ponzio, Calefato, Petrilli, 2006).

Braudrillard, instead, takes and carries to the extreme the idea of a spectacularized function and in it he sees the main characteristic of the goods in a capitalist system, through which a dissolution of the object itself is operated.

To design products with a good level of usability, guidelines, and different standards have been developed. The various authors who have studied to clarify the concept of usability have found themselves in trouble to trace its borders. Currently, the author who seems to find favor of the HCI (Human Computer Interaction) community is Shackel, who states that the usability of an artifact is its ability, in terms of human cognitive characteristics, to be used easily and effectively by a specific category of users to carry out activities within defined environmental contexts.

Shackel was among the first to develop the usability model. This model dates back to 1991 and at the conceptual level starts from the acceptance that declines in utility, usability, likeability, and costs.

Jakob Nielsen, instead, defines usability as the extent of the user's quality of experience in interaction with something, be it a website or a traditional software application or any other tool with which the user can operate. According to Nielsen, a product is usable when it is easy to learn, allows for utilization efficiency, is easy to remember, allows few, low gravity interaction errors and is pleasant to use.

Conceptually, the usability of a product measures the cognitive distance between the design model (product model and its operating mode owned by the designer and incorporated in the artifact) and the user model (working model of the product / service which the users construct by themselves and which

regulates the interaction with it). Although usability is one of the dimensions that define the overall quality of an interactive product, it is measured by its interface, which should expose immediately its peculiarities, limits and modes of operation, highlighting the relationship between actions that the user can perform on the same interface, and the results that can be achieved. Its analysis should provide guidelines for the design and redesign, in fact, the usability center is the knowledge that each alternative design should be evaluated by potential users, in order to have sufficient margin to correct wrong design choices, caused by not taking into account the physical and cognitive characteristics of end users.

The user needs have assumed, therefore, a particular quality characteristic that has been revealed in the recent past and that today requires the design process should be given a renewed attention to the functional rules and a marked sensitivity to the needs of users ; each individual is different, more or less able about physical and cognitive condition in relation also to the personal experiences and stages of development. […] The result of a design which is conscious of the needs is the construction of more and more "well-performing" setting, suitable to be "experienced" by the people who have "different profiles", which move interacting between themselves and with the environment itself (Garofolo, Conti, 2012).

For example, the blind receive information needed for the construction of a real world primarily through the tactile and auditory perception, as well as through kinesthetic experiences. The auditory sense is a very important aspect of the orientation of the blind, as it allows them to move safely in a structured space, and gives them the power to sense the presence of obstacles.

Beside the auditory sense, the blind person makes use of the sense of touch, which plays an important role in the development and acquisition of concepts. The sense of touch is used not only statically but also in a dynamic and exploratory way (active touch). […] Tactile perceptions are received through any part of the body, but primarily through the hands that are the privileged organs of touch. Hands, through careful and accurate palpation, identify the different details of the object to "understand" and permit, therefore, the blind person to get a mental picture of the object and acquire the spatial position (Bilotta, 2002).

In the planning stage, the study of emotions and perceptions are important because they affect the actions of people, their expectations, their plans with respect to products that they meet and deal with. Referring to the emotional aspects, Donald Norman draws up a classification of three different levels of the human brain: the visceral level [emits quick judgments about what is good or bad, safe or dangerous, by sending the proper signal to the muscles and alerting the rest of the brain], the behavioral level [site where the large majority of human behavior resides] and reflective level [covers the control function and general reflection]. Such levels reported in design differ from one another and, in particular visceral level is pre-awareness, pre-thought, where what counts is the first impression, the initial impact of a product, the appearance, the tact, the sensations it produces; the behavioral level concerns the utilization, the experience the user has about a product: function, performance, and usability; finally the reflective level where lies the conscience and the higher degrees of feelings, emotions and reasoning.

La distinzione fra il pensiero esperienziale e quello riflessivo merita di essere presa in considerazione, e questo almeno in parte perché molta della nostra tecnologia sembra costringerci verso un estremo o l'altro. Con gli artefatti adatti potremmo potenziare ciascuna modalità cognitive (Norman, 1995).

[The distinction between the experiential and the reflective thinking deserves to be taken into account, at least in part because much of our technology seems to force us to one extreme or the other. With the proper artifacts, we could strengthen each cognitive modality].

The experiential cognition includes mental states, in which we perceive and react to stimuli from the environment efficiently and without appreciable efforts. This condition manifests itself mainly through the unconscious stages of human behavior, drawing directly from the experience and knowledge already

stored in the user's mind. In fact *l'elaborazione esperienziale comporta una certa attività intellettuale, ma è simile ad un riflesso in quanto l'informazione rilevante deve già esistere nella nostra memoria e l'esperienza non fa altro che riattivarla* (Norman, 1995).

[the experiential processing involves a certain intellectual activity, but it is similar to a reflection, in that the relevant information must already exist in our memory and what experience does, is just reactivating it].

2.1 Methodological and behavioral dimensions – human center

The present work has been structured on new methodological dimensions that identify common protocols of activity on which to base the design process, interdisciplinary and shared, aimed at setting up new passenger seats in the cabin can be adapted to different user needs and with the integration of new technologies and materials.

The structure of the research aims to discover a "creative" methodological approach, based on the need to address the difficult challenges that contemporary society imposes at an increasingly rapid pace, entrusting to the discipline of industrial design the enhancement of the cultural capital or, more avowedly, to facilitate the transition from the material to the immaterial cultural capital through the instruments of knowledge, skills, and creativity. The methodologies applied to the industrial design discipline and the evolution of the same discipline methods, underpin the cultural and scientific background knowledge as a starting point for the construction of thought as a response to the needs; they are also based on the skills that, starting from knowledge, surpass it, complementing and making it operational; the whole thing coming through the instrument of creativity for the achievement of the proper and necessary balance between intuition and reason, design and science.

Such research starts from the methodological basis, which places man at the center of the design process, in which the designer's role becomes more complex, since, beyond knowing the techniques, he/she must also provide a formal value to the product, and must be a careful observer of the reality around him/her to interpret the experience of people, including through the support of cognitive sciences. People interact with the artifacts, as Donald Norman points out, through the synergy of three different mental images, the first is the image in the designer's mind, "the designer model", then there is the image the user has of the device and its functioning "user model" and the third is the system image. In an ideal world the two models should be identical and, accordingly, the user should understand and use the object in an appropriate manner; unfortunately, this does not always happen, designers do not communicate with end users, they just provide the product specifications.

This complexity of knowledge has meant that, especially in cognitive science, a strong interest has been developed in the anchoring process of new information on old, on a combination of knowledge from different areas, the integration of knowledge resources often fragmented between different actors [and] of re-use of the acquired knowledge (Anselmi, 2009).

Therefore, Norman, as an experimental psychologist, focuses on the ways in which people interact with the artifacts. In describing the interaction with objects, he uses a human action model [Fig. 1] consisting of seven stages, where there are two possible problem areas that need attention in the design, the execution "hemisphere" defines the transition from the emergence of an intention to formulate a sequence of actions necessary to implement them, while the "hemisphere" of the assessment defines the effort needed to interpret the system status and to determine its compliance with the intentions. It is on this theoretical foundation that has been developed the "UCD_Ucer Center Design" methodological approach [Fig. 2], which is the ability to detect, through structured and verifiable methods, experiences and user requirements and turn them into design and evaluation tools.

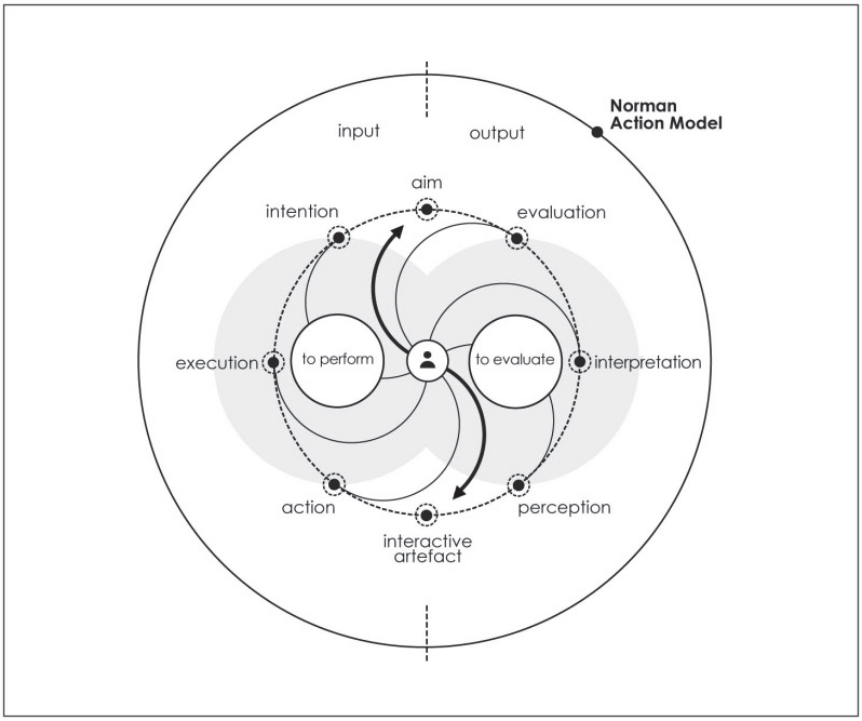

Fig. 24 Action Model of Norman (1991), freely interpreted by Capece S. (2009)

Inverting a J. Rubin's well-known definition, we can say that the UCD is not just a philosophy of intervention that puts users at the center of design and manufacture of products, but also, and primarily, the techniques, processes, methods and procedures necessary to verify and design the usability of products and systems (Rizzo, 2009).

In literature, there are a different set of principles behind this design method. In 1985, Gould and Lewis identify four basic principles on which to develop a project aimed at the acquisition and evaluation of user needs. The first principle focuses on users and their tasks; the second principle concerns activities through iterative cycles of planning, evaluation and redesign, where the planning stage is followed by the assessment of the system, together with the users, before getting to the final implementation, and verify that it has fulfilled the established requirements, while the fourth and final principle regards the presence, within the work team, of multidisciplinary skills.

The UCD is configured, in fact, as a cyclical pattern based on continuous monitoring of the assumptions and design solutions, and the ability to capture and translate, in terms of project implementation, targeted information which is used at each stage of the production process and product development. The methodological path of User Center Design in the 90s and specifically in 1999 was expanded to include project activities sanctioned by the standard ISO 13407 in human-centered design processes.

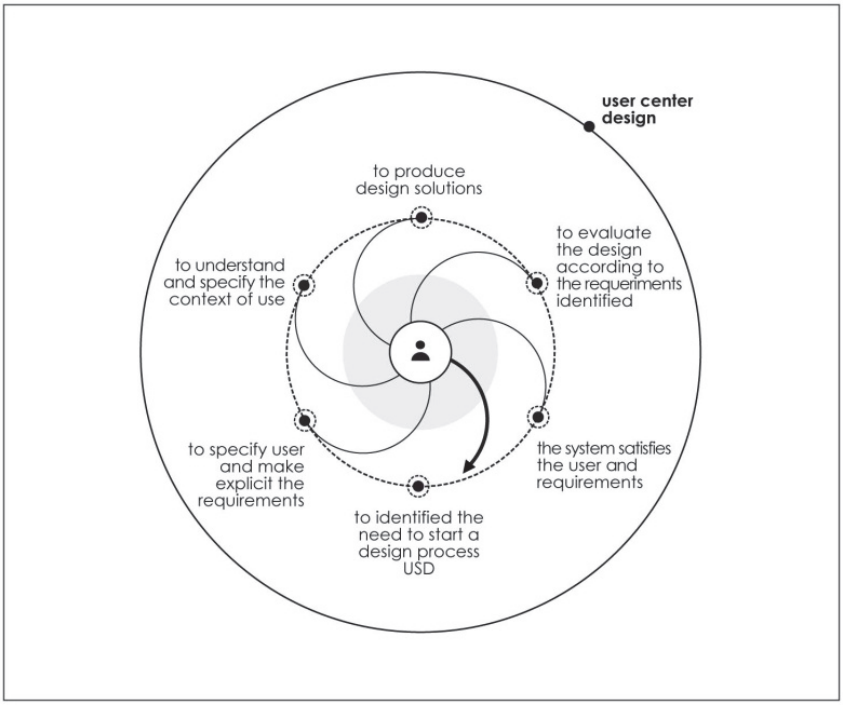

Fig. 25 Model of user centre design: user indirect participation, Rizzo F. (1999), freely interpreted by Capece S. (2009)

The activities that define this process consist of the identification of a need; understanding and specification of requirements and user characteristics, production of design solutions, design evaluation with respect to the identified requirements and the satisfaction that user gets by the system.

Since the '90s, the User Center Design has undergone an evolution going from the design of computer-based interactive products to the design of products and services and also, by changing the original purpose, from design method for usability to design method of user experience. The user experience [Fig. 3], broadly defined and addressed in the design discipline, sets as a basic element in the design path, the study, and research on the same user experience by placing the latter at the heart of the process. We can therefore state that *while the traditional UCD has dealt to identify problems that users showed during the interaction with the products and how to resolve them, the experience-based design has produced some new themes for reflection and application of design such as designing for the user experience, find inspiration by the user, the empathic design, and hedonism. From a design point of view, the study of emotions is relevant to the design itself as these are a not negligible aspect of the experience, they influence people's actions, their expectations, their future plans with respect to products they meet and relate to* (Rizzo, 2009).

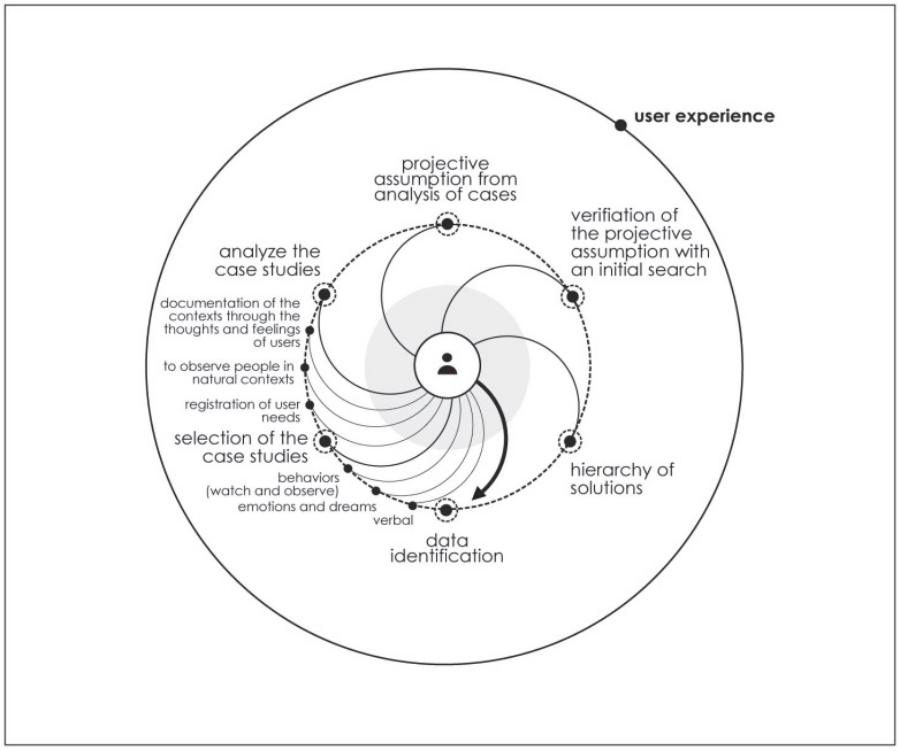

Fig. 26 User experience: indirect experiential participation, Rizzo F. (1999-2003), freely interpreted by Capece S. (2009)

The experience methods, unlike the traditional methods found in User-Centered Design, build the project on the basis of user's dream, their imagination and reworking of all that they have done, seen and known previously. In this regard, Jane Fulton Suri, chief creative of Iseo, argues that «*through observations designers can learn, through empathy they may be inspired to imagine new and better solutions for people* (Rizzo, 2009).

Moreover, to better understand the user experience, Jane Fulton Suri distinguishes three modes of action, the first one is to observe what people really do, both in their natural contexts and through prototypes which people may be exposed to, the second is to ask people to participate, either by registering their needs and documentation of contexts, or through the record of their thoughts and feelings; and finally the third mode deals with evidence and verification of the things directly, to get a personal perspective on an experience that is being designed and that is typically experienced by users.

The framework for action should not be seen as a scenario outlined to accommodate a sequence of actions and interactions, but becomes especially a context of meanings and possible social and cultural shared interactions. In this way, the environment, in which one or more actors are located, loses the connotation of a stable information provider and becomes a multi-componential scenario in which the actions take place and the information dynamically follow each other.

The context, as states Giuseppe Mantovani (1995), cannot be defined as something predetermined, but you need to consider the scenario of action as a space that is, at the same time, both physical and conceptual. Within it, the actors perceive the overall situation in which they are to act using conceptual models peculiar of their culture. Will be through the same action, also, that cultural models will be reviewed and amended making use of the information that the dynamic context offers.

3. The evolution of comfort models in the aircraft interiors

Comfort represents a subjective synthesis of the elaboration of the quality of the interaction between user, product and environment, and it is attributable to a complex set of tangible and intangible factors, such as physiological, physical and psychological.

Several definitions for the concept of comfort can be found in literature, *Pineau's (1982) definition of comfort included everything that contributes to human wellbeing and convenience of the material aspects of life, while Slater (1985) described comfort as the physiological, psychological, and physical harmony between human beings and their environment that ultimately deliver a pleasant state. Tiger (1992) highlighted a connection between pleasure and comfort by suggesting that the human brain, which monitors the comfort of the body, rejects pain and seeks pleasure* (Ahmadpour, 2014).

Furthermore, Dumur, Bernard, and Boy suggested four points of view towards comfort, psychological comfort is a state of quiet enjoyment and being free from worry and disappointment with regards to basic human needs (e.g. food, security, etc.), entailing aesthetics comfort (satisfying one's taste for forms, sound, smell, etc.), socialization comfort (incorporating the need for social relationships as well as privacy) and conformity (the sense of belonging to a group); physical comfort is the state of being free from issues pertaining to physical, physiological, and biomechanical states; sociological comfort is related to one's ethnic and social class, and, technological point of view in comfort refers to those material inputs from the environment that provide pleasurable sensations (Dumur, Bernard, Boy, 2004).

These concepts are the foundation of the interpretative models of the experience of comfort. It is particularly relevant the model [Fig. 4] proposed by De Looze et al. in which the result of the interaction process is defined as three macro levels: "human level", "seat level" and "environment level". Each of these levels exerts a specific influence in the definition of comfort and in the characterization of the respective/different variables. The human level represents the anthropometric variability of the user, while, the seat level is based on the characteristics and structural variables such as the inclination of the backrest, the width of the seat and the hardness of the pillow. Furthermore, the environment level influences on the comfort evaluation considering the activities performed by the user and the characteristics of the reference context (De Looze, Kuijt-Evers, Van Dieën, 2003).

The methods of De Looze et al. (2003) and Moes (2005) provide the basis of the theoretical framework [Fig. 4] proposed by Vink and Hallbeck (2012) in which the perception of comfort and discomfort is defined through the interaction between "product", "person" and "usage / task". *Perception process is dependent on the person, the object in work-space (seat), the purpose and why this object is used* (Vink, 2014).

In fact, the interaction effects are produced by the responses of the human body through postures, muscle movements and senses. These responses, according to the expectations, are perceived subjectively and interpreted as "comfortable", "you feel nothing" (no discomfort) and "feelings of discomfort".

Inside the aircraft, the users-passenger interact with the environment through the activation of their senses, starting by the visual impact continuing with the processing of external inputs of different nature (smell, sound and touch). These inputs are evaluated according to subjective factors such as user-passenger expectations, previous experiences and frame of mind, which influence the perception of the comfort during seating use experience.

Through the analysis of the user experience in the aircraft environment, Admahpour et al. (2013) describe a model [Fig. 5] regarding the comfort experience, in which is reported the relationship between the users-passenger and the perception as result of the seat-human interaction inside the aircraft. The authors

define the process of interaction as the result of a complex system in which there are multiple factors, such as “environmental factors” related to the physical and social aspects and the context of use, “human characteristics”, which include physical, anthropometric and psychological elements, and “expectations”, based on the expectations of users- passengers before and during the flight experience.

The model also includes, “time and activity”, represented by the influence of the activities carried out in the reference environment on the comfort evaluation, the "perceptions of cabin", as a general idea of the quality of the cabin, the “physical impacts”, relating to the postures and the movement of users-passengers, the “appraisal”, based on a subjective evaluation of cognitive processes (result of the seat-human-environment interaction), and expressed as positive or negative emotions.

Therefore, the frame of mind, also plays a significant role in how passengers live the flying experience. But it is only after the complex process of interaction that the perception (subjective) of comfort or discomfort is determined, which may induce the adaptation of the user-passenger in the reference enviroment, changing his position and/or the activity carried out.

Continuing with the analysis of the user experience, Admahpour (2014) focuses the method on the perception of the user [Fig. 4], filtered through psychological (“peace of mind”) and physical factors (“physical wellbeing”), including “proxemics”, understood as the control of the personal and social space, “pleasure”, “satisfaction”, associated with the efficiency, effectiveness and usability, and the “association”, regarding the interaction between the environment and personal feelings. Finally, the above processes determine the level of comfort or discomfort within a period of time and relating to the social context of the flight, that could influence the behavior or future choices of the user-passengers (Admahpour, 2014).

According to the previously described methodological aspects, the factors of comfort such as “human characteristics”, “expectations”, “physical impacts”, “appraisal”, “proxemics”, “pleasure”, “satisfaction” and “association”, have been integrated in the ergonomic principles and the good design values. These have been included for the configuration of a new and inclusive methodological-design model, and for the evaluation and validation of the arrangement between the shape design, dimensions and functionality of the passenger seats.

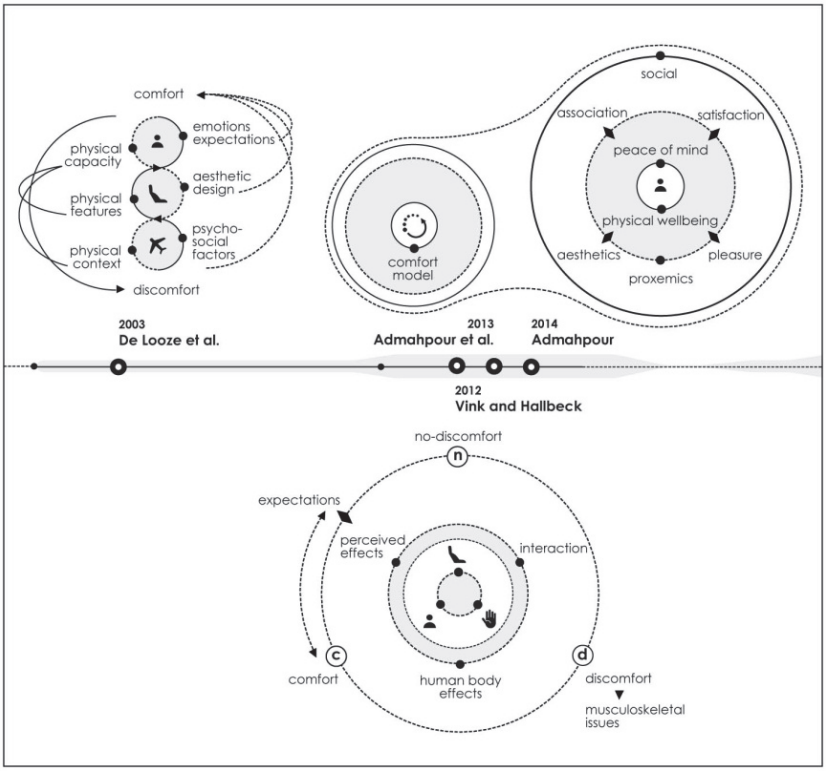

Fig. 27 Timeline of the evolution of the theoretical models of comfort in the aircraft interior based on the proposals of De Looze, Kuijt-Evers, Van Dieën, (2003); Vink and Hallbeck, (2012); Ahmadpour, Robert, and Pownall, (2013), this framework is illustrated to Figure 5; Ahmadpour (2014); the illustration of timeline is freely interpreted by the authors of the contribution.

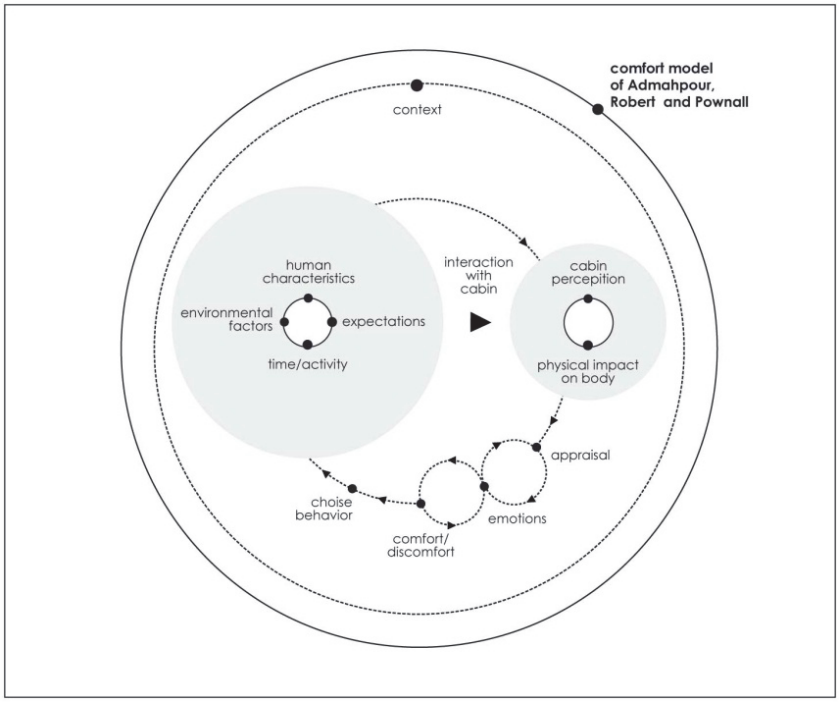

Fig. 28 A model of passenger comfort experience based on the proposals of Ahmadpour, Robert, and Pownall (2013), freely interpreted by the authors of the contribution.

4. Usability and comfort methods evaluation

The process of identification and analysis of the needs, which will be used for the ergonomic intervention, precedes the verification of usability and comfort conducted through the passenger seat evaluation by specialists and the involvement of a sample of users able to represent, for features, aptitudes and skills of use, those who use and will use the product.

The usability and safety testing methods are based on the collection of information concerning the manner in which the man-product interaction is performed within a given context of use, and make possible to identify and analyze the behavior of users, their needs and, finally, the type and frequency of errors that users can take when performing the required tasks (Tosi, 2005).

According to Wilson J. R., the test methods can be divided into methods of direct observation and methods of indirect observation. The direct observation methods are based on techniques of observation and evaluation of user behavior when interacting with the product. They are also defined objectives methods, as they are able to provide precisely the objective information, and consist of the collection of data relating to the behavior and performance of users during the execution of specific activities (Wilson, Corlett, 1995).

The indirect observation methods allow, instead, to collect information relating to the interpretation that users give to what they are doing. These are also called subjective methods and concern the realization of reports on the behavior, attitudes and opinions of users. Their subjectivity refers to the fact that the information produced is filtered by the observer's assessment.

Subjective measurements are considered an essential tool for evaluation, given that they collect information and problems resulting from the user's interactive experience. The theme of subjective evaluation has been widely debated in the literature, deeply analyzing multiple aspects that intervene on the very nature of evaluation.

The subjective evaluation is used to identify relations that cannot be analyzed without user assistance as, motivation, satisfaction, preferences, performance, usability and comfort. Psychometric tools, in this way, seek to create a multidimensional analysis of usability, measuring a complex set of variables. In fact, as pointed out by Kirakowski, the usability evaluation is a combination of subjective judgment, such as satisfaction, and objective data, such as performance. On the other hand, although there is interesting analysis on the multidimensional usability (Chin, Diehl and Norman, 1988; Glendon, Stanton and Harrison, 1994; Jordan, 1994) this issue has not yet been addressed through a systematic study that can provide the elements on which eventually some metrics can be built.

4.1 Subjective measurements through psychometric tools

The classification of usability methods in the literature is distinguished in an analytical approach based on structured tests processed by an expert and an empirical approach, based on the direct involvement of users.

The analytical assessments (also called heuristics analysis or expert evidence) are conducted by specialists who, on the basis of their specific skills, analyze the product trying to anticipate problems that typical users of the system can meet in different stages of use of the product.

Empirical assessments or user tests, instead provide for the direct involvement of a sample of users in the evaluation process. The tests with users rely on the realization of experiments and do not presuppose an absolute rigor of the procedures, but allow you to bring out a greater number of problems and to identify even unexpected aspects of a product usability.

The need to detect and monitor the perception of usability that users develop in connection with the use of the system has led to the development of different types of questionnaires that differ in theoretical constructs. The most used in the literature are listed below:

The Questionnaire for User Interaction Satisfaction (QUIS), developed in 1988, based on the assumption that the user's use satisfaction, considered as subjective satisfaction, is a relevant indicator of usability of the system (Chin et al. 1988; Wallace, Norman e Plaisant, 1988; Shneiderman, 1987). This tool, now in version 7.0 of development, is composed of eleven sections built in a hierarchical way (Harper, Slaughter and Norman, 1997): a personal data questionnaire, six scales measuring general impression on the system, four measures related to interface-specific factors, and finally an optional section that evaluates the online help and support manuals. The assessment is expressed on a 9-point scale.

The Software Usability Measurement Inventory (SUMI), developed by the Human Factors Research Group of the University of Cork (Ireland) in 1990, consists of 50 items, divided into five subscales, Efficiency, Affect, Helpfulness, Control and Learnability. The usability measurement scales have been developed taking into account the usability ISO 9241-11 definition of usability features that identifies it as the effectiveness, efficiency and satisfaction of a particular user, engaged in a particular task and use context. The assessment is expressed on a 3-point scale (agree, undecided and disagree). In literature there are conflicting opinions on the validity of the SUMI, by some is considered one of the best validation instruments (Baber, 2002), while others point out the lack of a comparative validation that provides a proof of the real ability of analysis.

The Computer System Usability Questionnaire (CSUQ) is an evolution of The Post-Study System Usability Questionnaire (PSSUQ) developed to measure user satisfaction in interaction with a system in laboratory environments through contextualized questions in the survey (Lewis,1992). The CSUQ differs from its predecessor because it is not contextualized, so it can be used out of the laboratory and is built to create stable factors of investigation. The concept on which it is based is that usability is related to standardized measures of satisfaction and the purpose of this tool is to provide them. The CSUQ consists of 19 questions on a seven-point scale with a range from "strongly disagree" to "strongly agree".

The System Usability Scale (SUS) was developed in 1986 by Digital Equipment Corporation and was implemented in 1996 as the global usability of a system in a context (Brooke, 1996). This tool evaluates the satisfaction meant as subjective response in the interaction with a system. The SUS does not use multidimensional metrics but attempts to capture the usability as the user's aptitude for a specific interface in a given context of use, referring to the ISO 9241-11 definition. The SUD consists of ten questions measured on a five-point scale, with a range from "strongly disagree" to "strongly agree".

The Usability Evaluation (Us.E.), developed in 1999 at the Cognitive Ergonomics Laboratory of the Department of Psychology, University of Rome "La Sapienza", starts from the assumption that usability is a multidimensional construct (Di Nocera et al., 1999; Di Nocera, Ferlazzo e Renzi, 2003). Initially built, in version 1.0, on four dimensions obtained through factor analysis has come, in the current version 1.1, to a composition in three dimensions: handling, satisfaction, and attractiveness. The Us.E. 1.1 consists of 24 questions with a five-point scale with a range from "Absolutely False" to "Absolutely True".

The Purdue Usability Testing Questionnaire (PUTQ) is a test consisting of 100 questions on the interface of the structured system of eight factors relating to the human-machine interaction. These factors are compatibility, consistency, flexibility, learnability, minimum actions, minimum memory load, perceptual limitation, help to operator.

The Experience Sampling Method (ESM) is a procedure developed to study the behavior and subjective experience in real life. In fact, this procedure is based on the real-time detection of self descriptions that the subjects themselves provide about the external situation and their state of consciousness during the occurrence of events. The testing period is usually one week long, with an average of 6/8 signals per day distributed according to a randomized scheme throughout the day.

5. Protocol for the evaluation of comfort – perceived usability of passenger seats

Starting from the study and analysis of the existing configurations in literature and the current patents of existing passenger seats and from the assessments of structural, feasibility, comfort and reliability analysis of the current passenger seats, new validation and evaluation tools of usability and comfort of passenger seats have been defined, in order to analyze and evaluate the various components of ergonomics of the seat through the observation of the interaction user-environment-product. The activities [Fig. 6] focused on the study of the requirements of the identification and the estimation of the parameters of comfort, as well as on the conception of design criteria suitable to obtain favorable conditions for end users, in order to configure a new ergonomic design of the seat and a proper level of comfort for the passenger even on medium-long distances, trying to avoid the so-called "economy class syndrome" that leads to serious consequences for the health of the occupant.

The aim will be to analyze and evaluate each component of the ergonomics of the passenger seat through the user-environment-product interaction according to a sequence that, starting from the physical-dimensional interaction condition and by the correspondence of the product to the anthropometric characteristics and to the capacity of users movement, involving aspects of perceptual and cognitive sphere, the emotional sphere, and finally to the social.

As a knowledge or set of knowledge, ergonomics is a wealth of knowledge and analytical tools that can become a tool for innovation and stimulating factor of the creative process to which the ergonomics provide the ability to imagine and analyze in a structured form the multiplicity of situations and conditions that define and determine the interaction between user and product (Tosi, 2005).

In detail, the quality of interaction between the user and the seat, the assessment of compatibility between the characteristics of the product, the specifications, and the user's physical abilities, the activities that this place and achieved performance, have been taken into account.

The first phase of evaluation focused on the identification of the dimensional parameters of interest and of the relative anthropometric parameters. These parameters will be reported both to the static and dynamic dimensions. Similarly to the definition of anthropometric indices, there is the need to identify the categories of users targeted by the project and their physical and dimensional characteristics, the specifications of the planned and / or likely actions, and the constraints imposed by all the context variables.

In parallel, the emotional components oriented to the study and design of the subjective aspects of the interaction user/passenger seat will be evaluated. Among these, the emotions psychology, the areas of social and anthropology studies, while developing evaluation and intervention methodologies which are distant both from disciplinary origin and as intervention languages and tools, include and assess the subjective dimension of interaction, to date remained at the margins of the ergonomics interest.

User feedback in this case will be represented by system usability, i.e. the effectiveness, efficiency and satisfaction that specific users can experience using the product within the reference airplane cabin, by the comprehensibility of the information available and the language in which they are presented, by the ease

by which you can carry out the control procedures and/or dialogue, by the opportunity to receive appropriate feedback at the end of each procedure.

Taking into consideration the tactile properties of the materials used, as well as sensory effects produced by the formal solution proposal, the color and the surface treatment of the passenger seat, the relationship will be established between the proposed seat and the sensory quality actually perceived by the user.

In referring to the subjective requirements of usability, factors related to the direct experience of the use of the product and the ease by which you can carry out the operation will be taken into account, through a perceptual and emotional dimension and the ability to meet the most strictly subjective needs, related to user satisfaction.

To further ensure that the seat provides comfortable performance in the design phase and evaluation, we must take into account the variability of parameters such as, the "seat pitch", the "backrest and seat pocket" and the "human body space" (Vink 2011).

This paper has chosen to treat analysis and the passenger seat assessment in respect of each component of the ergonomics, human factors (physical ergonomics); user-centered design and new human factors (user pleasantness), which highlights aspects and specific meanings of quality, intended as user-seat quality of interaction.

The planned tests will be based on both direct and indirect observation methods that will be organized according to the following sequence:

- the test of Physical Ergonomics – Human Factors (Quality = compatibility) to assess the physical characteristics of the session, the physical, physiological and psycho-perceptual abilities of the tester, the characteristics of the activities to be performed and the physical – social context in which activities will be carried out;

- the User-Centered Design test (quality = compliance to the use) to evaluate the ability of the product (seat) to respond to the needs posed by its use within a given context;

- the New Human factors test - Comfort of use (quality = value - User pleasure) to evaluate the comfort of use attributed to the relationship with the seat, that is the judgment that users express, consciously or not, in terms of annoyance, appreciation, strangeness or familiarity with the product.

In particular in the first test – Physical Ergonomics – Human Factors – will be defined and evaluated the dimensional and functional requirements characterized by compatibility between the characteristics of the passenger seat and the context in which this fits; the specifications and capabilities of users as well as the constraints and the variables of the reference environment. Therefore, the compatibility between the users' body size (static and dynamic), the reachability zones and the spaces of movement necessary to perform the given task, will be specified. Similarly, the size of the physical environment taken as a reference (dimensional requirements); the compatibility between the characteristics and physical abilities of the user, the physical activities required and the physical size constraints posed by the seat and / or the cabin, will be analyzed.

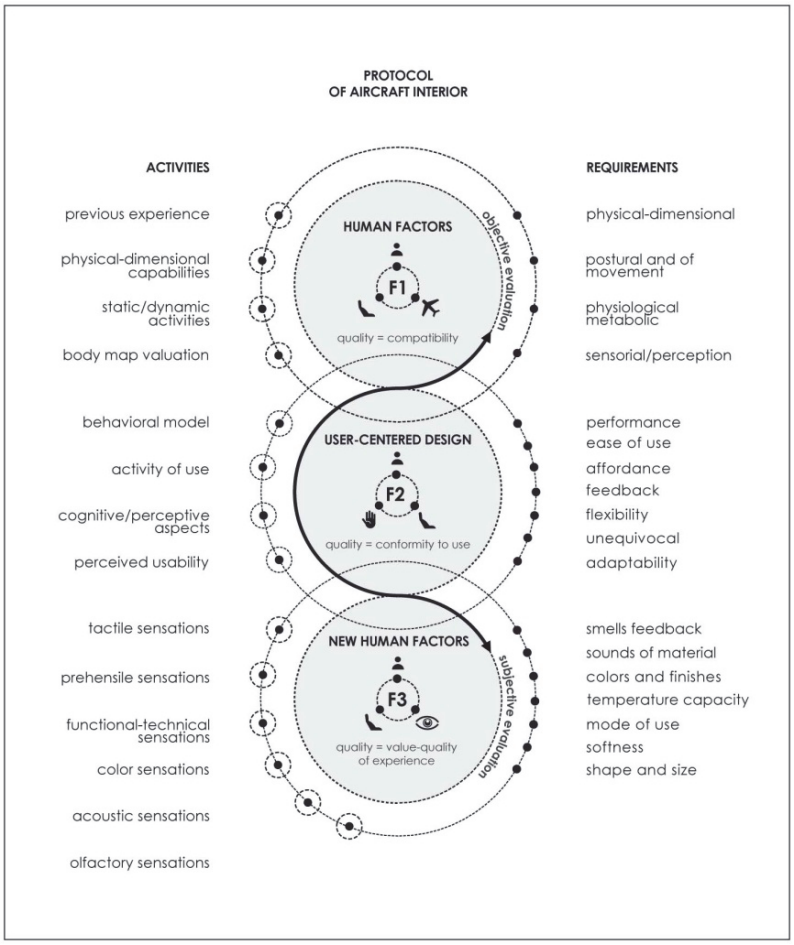

Fig. 29 *"Ergonomia per il progetto" Tosi F. (2005), freely interpreted by the authors of the contribution.*

The definition and comparison of dimensional and functional requirements will be based on knowledge of the anthropometric characteristics and physical capabilities of the human body and will require the identification of the group of user to which the project targets and, in parallel, the analysis of physical activities to be performed.

In the second test – User-Centered Design – the interaction subjective dimension, contextualizing the results of analysis and supporting the user's active involvement, will be evaluated and defined. The user will have to simulate the use of the seat as it happens in real life since the behavior pattern associated with the reference activity will be detected. The performance, ease of use, affordance, feedback, flexibility, correspondence to a predefined conceptual model, unequivocalness and adaptability will be analyzed, in order to record the types of error and difficulties encountered.

The relationship between the user and the product is a dynamic process with many facets, which concerns perceptual and cognitive aspects of the use of the product, how it is absorbed the information that comes from the product, how it is interpreted and which user actions they are a result of.

In the third test - New Human factors - pleasantness of use - the characteristics and reactions of the subject that can be measured using the techniques developed by cognitive psychology will be assessed and defined. The goal will have to assess the aspects of sensory pleasantness of the passenger seat, covering tactile sensations (shape and size of the object); prehensile sensations (the quality, the softness,

the grip capability of the surface); functional sensations (use modality and activation); thermal sensations (the conductivity and the heat capacity); chromatic sensations (colors, surface finishes and the chromaticity of the object); acoustic sensations (loudness of the material, of action, of the detectors, and acoustic feedback) and finally the taste and olfactory sensations.

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