Development of a Method Based on Ergonomics Activity Analysis in Order to Enhance Knowledge and Skills in Product Design Comfort

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ABSTRACT

This paper's purpose is to present and propose a method to enhance knowledge in comfort and discomfort in aircraft interior design, under Ergonomics Activity Analysis (EAA) methodological approach. Literature shows that comfort is an important subject to consider in competitive airlines market that may improve and differentiate companies and brands. Making a literature analysis and review, it was possible to verify that development of comfort in aircraft interiors design project is no easy task for engineers and designers. Moreover, comfort and interior design in aircraft are guided by several standards and rules, and these restrictions might diminish the possibilities on creation process. Notwithstanding, this paper proposes a multidisciplinary method originally developed to study comfort and discomfort in aircraft interiors, which are finally shown to be affordable to enhance capability in design product project.

Keywords: Passenger Comfort and Discomfort; Aircraft Interior Design; Automotive Interior Design; Product Design Capabilities.

INTRODUCTION

This paper is the result of research developed with the prime purpose of investigating comfort and discomfort relations between users and aircraft interior environment, under ergonomics activity point of view. By the end of this research, it was verified that the proposed method not only allows a better understanding of which parameters may provide comfort or discomfort, but also may render capable designers by stimulating their perception, creativeness and promoting technological innovation.

The Cabin Comfort and Design Project

The studies here presented are part of a much bigger project, where several researches were done to better understanding of the factors that interfere in passengers comfort and discomfort, under varied areas of knowledge point of view - ergonomics, thermal comfort, atmosphere pressure of the cabin and vibrational acoustics.

The integrated project "Cabin Comfort and Design – Integrated Analysis and Development of Criteria for Comfort", which is part of PICTA (Programa em Ciência e Tecnologia Aeroespacial), was sponsored by FAPESP (Fundação de Amparo a Pesquisa do Estado de São Paulo), FINEP (Agência Brasileira da Inovação) and EMBRAER (Empresa Brasileira de Aeronáutica S/A). There are three education and research institutions taking part of this project – Universidade de São Paulo (USP), Universidade Federal de São Carlos (UFSCar) and Universidade Federal de Santa Catarina (UFSC).

Our ergonomics research group worked with the purpose of investigating activities performed by users in aircraft passenger cabins, under Ergonomics Activity Analysis (EAA). As an inspiration source for this task, Participant Observation (PO) method was used. Being so, researchers performed several activities, playing the role of users, for better understanding of relations between environment, objects and common activities. To that end, the method here proposed uses social sciences techniques, to promote deeper understanding of activities, as well as a resource for technological innovation and new products creation for design and engineering.

In this way the method used to respond to a specific demand and provide information on users activities and necessities, has shown to be efficient in qualifying designers, once the researchers that took part in this investigation, by playing the role of users, happen to be students or professionals in engineering and design area. Therefore this method, with all it's protocols and tools may be used in manufacturers environment, in research and development areas of new products, and this is what this article presents.

THEORETICAL DISCUSSION

Comfort and Discomfort – (dis)comfort

When doing bibliographical research, one may verify that comfort is an important issue, to increase value and to distinguish airlines and automotive sector products (Ciaccia & Sznelwar, 2012; Grosjean, Neboit, & Lorraine, 2000; Rossi, Greghi, Menegon, & Souza, 2012; Silveira e Silva, Sznelwar, & D'Afonseca e Silva, 2012; Vink, Bazley, Kamp, & Blok, 2012). On the other side this literature study makes it evident that developing comfortable products is no easy task. Comfort and discomfort subjects, or simply - (dis)comfort by Vink & Hallbeck (2012) – are a vast field still to be explored, being fully in discussion in both point of views, as conceptual as well as to the technical analysis methods.

As one can see in several authors' articles, (Dumur, Barnard, & Boy, 2004; Ciaccia & Sznelwar, 2012; Rossi, Greghi, Menegon, & Souza, 2012; Vink & Hallbeck; 2012) the concepts and theoretical models on (dis)comfort have evolved, but there hasn't been achieved a consensus on what characterizes comfort or discomfort. Besides that, there are varied techniques and tools to check comfort, but once it is a subjective feeling, that may be originated by diverse types of stimulations, and even bound by peoples' emotional condition and life story, it may vary in such way that controlling variables influence becomes highly difficult. The most recent model to represent comfort was proposed by Vink & Hallbeck (2012), issued on Applyed Ergonomics magazine, in the editorial of a special edition on comfort. So according to the bibliographical references presented in this editorial, as well as other authors presented earlier in this article, the evolution of concepts and models on comfort and discomfort have evolved according to what will be displayed on the following paragraphs.

First of all, one must present a few concepts and definitions on comfort. As one can see in De Looze, Kuijt-Evers, & van Dieën (2003), and Keith Slater (1985), in his book Human Comfort, he defines comfort as a "pleasant state of physiological, psychological and physical harmony between a human being and its Environment". In the other hand, it is possible to see on Webster's Dictionary comfort defined as "a state or feeling of having relief, encouragement and enjoyment".

Under model evolution point of view, one may say that discussion on comfort and discomfort began on the 1950's, when the first studies on the sitting posture were done – that is the most relevant position in case of an airplane, train

or car traveling, since it is the position in which one remains most of the time. One of the earliest studies one has access, was done by Hertzberg (1958), where the concept of comfort was associated to the absence of discomfort, a[redacted]s. This model, created in the late 1950's was used until the end of the following decade, when a new proposition came up with continual scale, where comfort and discomfort would be the extreme points of an hedonic scale, as the one on figure 1 (Shackel, Chidsey, & Shipley, 1969; Richards, 1980).

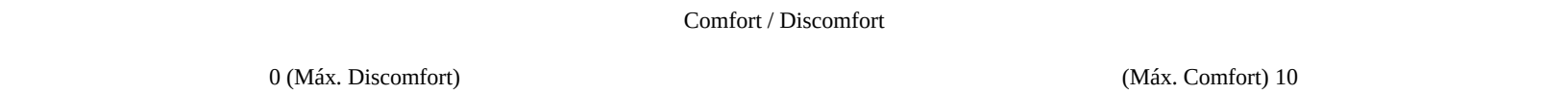


Figure 1. Continuous scale of comfort and discomfort. (based on Shackel, Chidsey, & Shipley, 1969; Richards, 1980)

Later in, the 1980's, some authors began to observe that using subjective variables brought one kind of results, while with objective variables, another kind of result. The difficulty arised by the disparity of results made them realize it would be better treating comfort and discomfort in separate. There should be two scales, one for comfort and another for discomfort (Kleeman, 1981; Kamijo, Tsujimara, Obara, & [redacted] Drudy, 1996; Helander & Zhang, 1997). The separation of scales is done with the goal of evaluating different aspects so that a person may have positive sensations (comfort) in some ways, while simultaneously feeling unconfortable in other ways. This sort of response may even vary in time, so that a multidimensional model may also be proposed, besides the linear ones shown in figure 2.

Figure 2. Separated scales for comfort and discomfort. (based on Kleeman, 1981; Kamijo, Tsujimara, Obara, & Katsumatu, 1982; Zhang, Helander, & Drudy, 1996; Helander & Zhang, 1997)

To better distinguish sensations and stimulations that may influence on comfort and discomfort, in 2003, De Looze and his colleagues created a new model which is shown in figure 3, so one can have a better understanding on the relation between the several types of stimulus that lead to discomfort sensations.

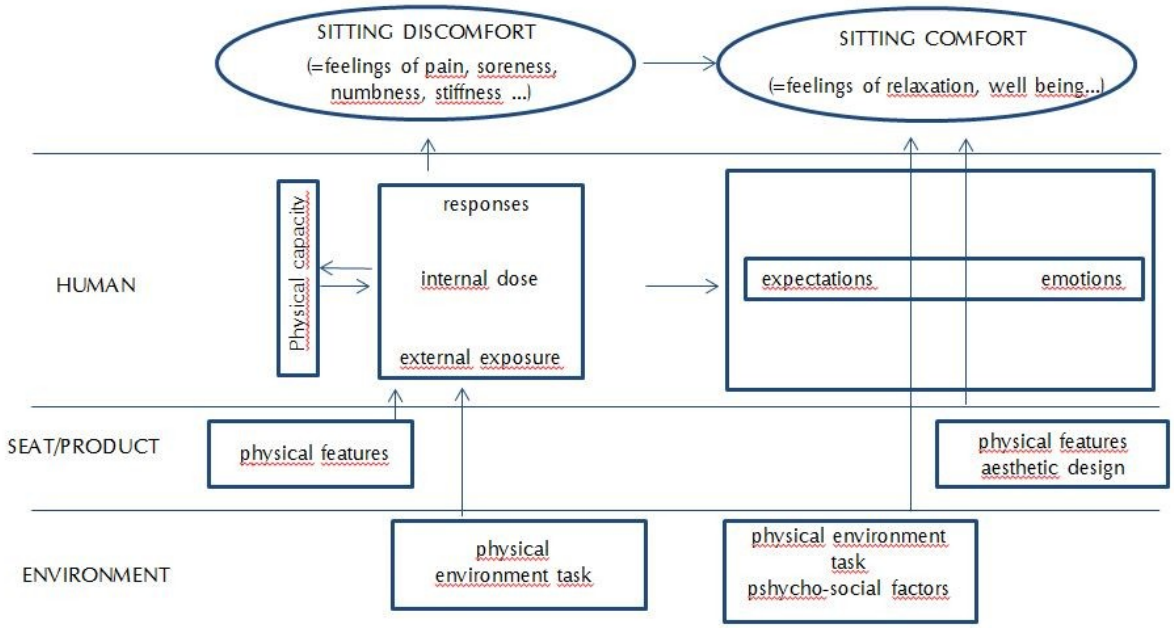


Figure 3. Theoretical model of comfort and discomfort and its underlying factors at the human, seat and context level (adapted from de Looze et al., 2003)

At last, in 2012 we come to the most recent model presented in literature. In this model, Vink & Hallbeck (2012) propose a revision of the model presented by Looze e his colleagues (2003). Figure 4 illustrates the model proposed by Vink & Hallbeck (2012), where we took the liberty of adding to discomfort results, for in our trials, besides the muscular-skeleton discomforts there were also visual as well as object manipulation discomforts, due to difficulties on usability and propitiation.

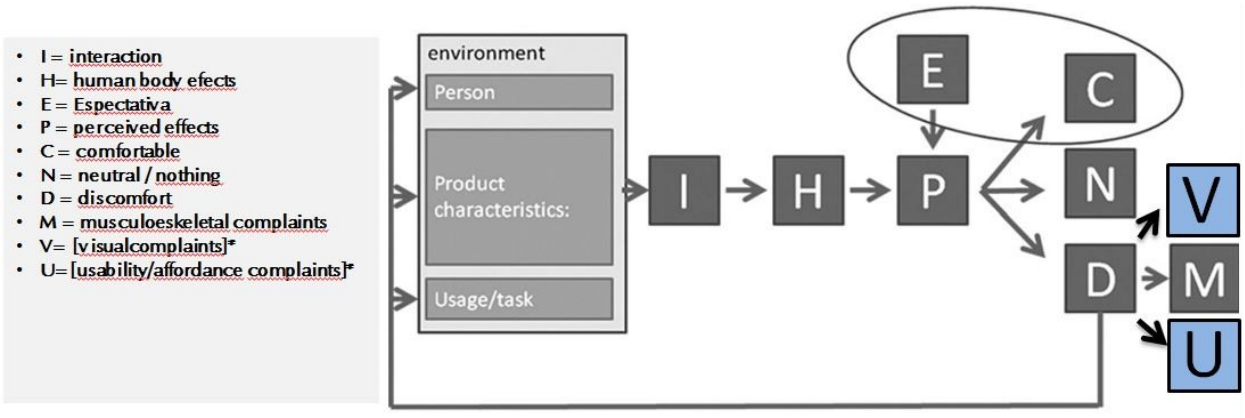


Figure 4. New comfort model based on the Vink & Hallbeck's bibliographic review, with two new discomfort results proposed by us (adapted from Vink & Hallbeck, 2012)

The main excuse to add these two subcategories on discomfort classification are connected mainly to issues on luminosity, reflections and obfuscation, as well as the lack of adjusting of objects, making actions more difficult.

To finalize this section, we place the definition for comfort used in our research group, with a user-centered point of view: “Comfort is the result of conditions available, so the person can perform with utmost dexterity whatever action he may wish to perform” (Sznelwar, et al., 2008).

Ergonomics Activity Analysis (EAA), Usability and Affordance

First of all, it is important to make clear that Ergonomics Activity Analysis (EAA) is a terminology derived from Ergonomics Work Analysis (EWA) and, its evaluation methodology is mainly concerned with operator's activity. However, in our case, it is used to analyze users' activities, which is why we establish a relation between this methodology, with user centered design, usability and affordance.

When developing a product or environment project, one of the basic principles of ergonomics that must be taken in account, is that of adapting labor conditions and product manipulation to human being instead of the opposite (Panero & Zelnik, 2002). This statement may be considered one of the main motives for creating accessories and adjusting devices in products such as chairs, armchairs and general furniture that must attend diverse needs of users who, on the other hand, may present a varied range of characteristics – race, gender, age, weight, height, among others, since non adjustable products will hardly attend all users' varied characteristics and activities. In addition to all that, according to several authors (Tilley, 2005; Panero & Zelnik, 2002; Iida, 2005; Kroemer & Grandjean, 2005) anthropometry (physical anthropology) associated to cultural values (cultural anthropology) constitute a high point in matters involving transfer of technologies – named anthropotechnology, according to Wisner (1979, apud Wisner, 2004) – dedicated to projecting products that shall attend human needs. Therefore, one must take into consideration physical dimensions and their intra and inter-individual variations, as well as cultural variations on object and environment using, with its facilities, difficulties and strategies of use, rendered by design, which must guarantee proper usability and affordance.

When starting a new project, one must build an "library" of situations, which according to Shön (1994; apud Daniellou & Béguin, 2007) will improve understanding on user activities. In carrying on research with these statements in mind, we chose an ergonomic approach on the activity, of francophone origin, as one may see in Laville (2007). At this point it is important to emphasize that this theoretical approach was originated in France and Belgium, with the need of understanding adversity in working environments, and the aim of improving working conditions of laborers. In this article related to passengers' comfort, approach has been centered on activities in order to improve understanding on relations between user, environment and objects.

Hence when establishing a theoretical relation between several concepts in activity centered approach, on systems and their interfaces, as well as their usability, in conception it can be said there has been an evolution in understanding of the relations between human being and artefacts and activities. According to Folcher & Rabardel (2007), at first came the concept of "man-machine interaction" where the system presents responses to human commands, in the presence of information exchange between hardware, software and user (Montmollin, 1999). One must mention that, instead of interaction here stands usability, since devices are meant to be used by humans, while interaction happens amongst humans. Later, the "man-machine system" concept is defined as a sole set, constituted of two principal components (man and machine) which work together in performing tasks, in such way that operating system combination of humans and machines may bring positive (success) or negative (failure) results related to the task. On this train of thought, the system may be composed by humans on one side and tasks on the other, with activity being intermediated by machines or devices used by humans in order to perform the proposed tasks. This way the mediated activity concept, proposed by Vigotsky in 1930, is our main reasoning conductor.

This conceptual evolution has become more complete as well as more complex. At this point a new diagram is proposed by Folcher & Rabardel (2007), with the instrument as a central point of intermediation between the subject of the activity, the other subjects and the object of the activity (task, result, regulation). In the next diagram, (figure 5), the instrument is an evolution of the artifact, since the latter is an object, while the instrument may be modified according to the nature of its use, of cultural changes and in interactions where it may be re-signified. This concept has a direct relation to the affordance concept, in a way that every user may give a different use to an object, for although a designer team may build it with a determined purpose, the user may re-signify and modify its use. This is one of the underlying reasons to stimulate the perception of engineers' teams, especially when you wish to create something new, to attend several kinds of activities.

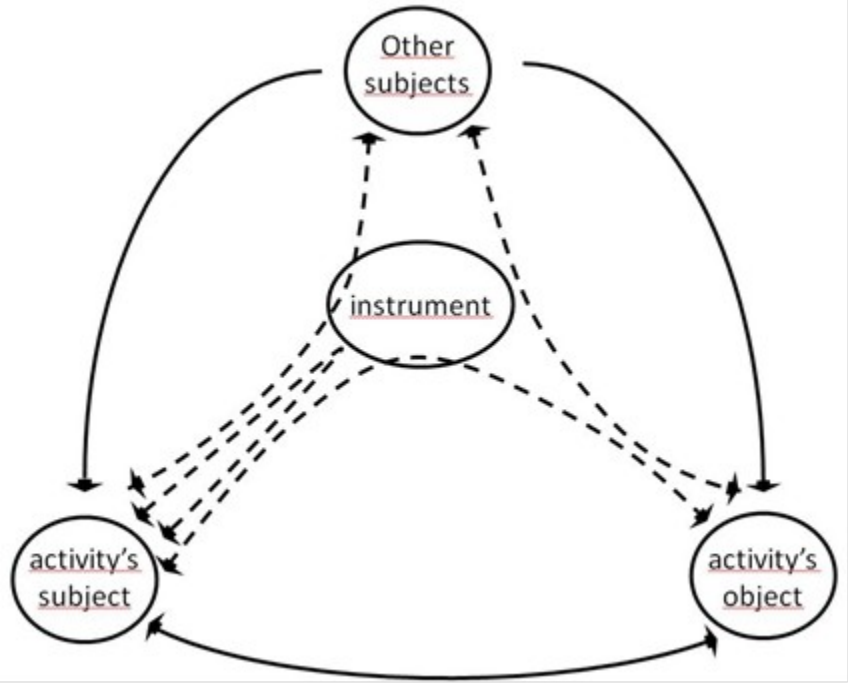


Figure 5. Activity . (Folcher & Rabardel, 2007)

Participant Observation (PO)

The study here presented has a user/passenger activity centered approach. The uniting of several methods, protocols and approach techniques of ergonomics activity previously presented, together with human sciences techniques, more specifically from anthropology and Participant Observation, render a better understanding of the phenomenon experienced by users, in a deeper sense and the acquisition of qualitative character information.

The research protocols and techniques used in our studies have their origin in ethnographical studies and the Participant Observation method, developed by anthropology researchers, at the beginning of the XX century (Bernard, 1998; DeMunck & Sobo, 1998). This method and its tools were created when trying to unveil the indigenous' life style, in their natural environment (DeWalt & DeWalt, 2002). In order to do so, it became necessary that researchers took part of their daily living, by experiencing their day-to-day in cultural immersion, thus allowing the researcher to put himself on the subjects shoes, by doing the same daily tasks and activities of a native (Marconi & Lakatos, 2011; Schensul, Schensul, & LeCompte, 1999; Kawulich, 2005).

This moment one must point out that this research has been drinking on human sciences and ethnographical research fountains, in order to adapt and use their techniques. In other words, this is not the "Participant Observation" in its pure form, with the experiencing and exploration, but an adaptation of the techniques, so that researchers may better understand the necessities of the user of the studied product.

Therefore, for the assays' realizations they were used systematic observation techniques, in order to describe, detail and analyze the forms of the environments' use – passengers' cabin - and the objects - seat, table, arm supports, spot illumination, personal adjustable ventilation.

In order to do so, assays were always performed in pairs, with one researcher in the user role - experiencing the action and analyses its own activity - while the other researcher was the observer, taking notes on the postural variations. Aside of the realization/observation of tasks, videos were made, so activities could be reviewed, their difficulties, facilities and strategies, when writing reports. The next session carefully describes the method, as well as the adaptations of the Participant Observation method for the assays.

METHOD, PROTOCOLS AND TOOLS

The method we propose was built in six stages which allow the designer to unravel users' needs in product design and propose changes in an existing product or even create a new one, with base on the facilities/difficulties found in the products used during the research, as a reference for something new.

We shall describe this study, and the concepts used that justify the practical actions will be exposed to provide a deeper understanding of theory and practice relation. In figure 9 we present the followed stages and the actions taken in each of them are described in the subsequent sections.

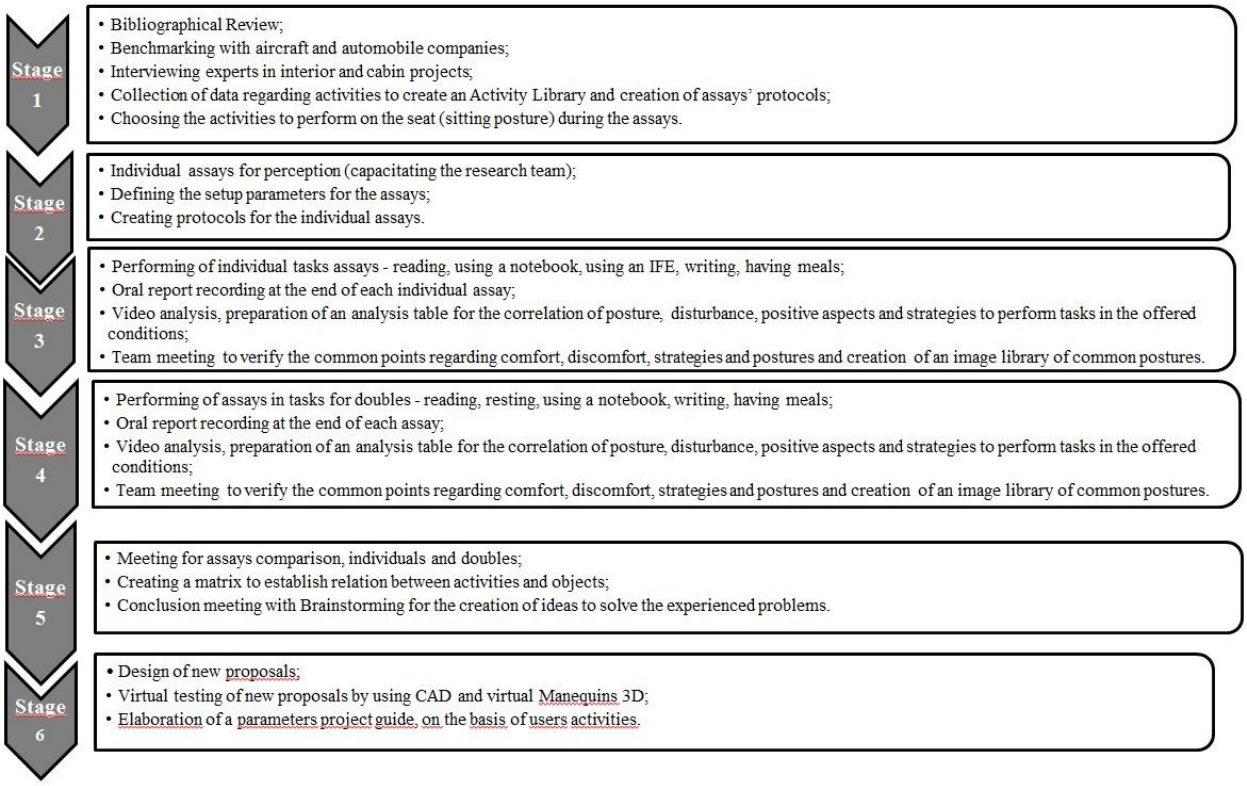


Figure 6. Research Stages.

Stage 1 – Starting point

This study began with a bibliographycal research on Ergonomics Work Analysis, Ergonomics Activity Analysis, ethnographic as well as Participant Observation methods and tools, besides the reading of magazines specialized in aircraft interiors - mostly Aircraft Interiors magazine - as well as consulting norms established by ANAC (Agência Nacional de Aviação Civil), IATA (International Air Transport Association), SAE (Society of Automotive Engineers).

After an initial phase to familiarize oneself with the research theme, we visited several companies in the branches of aircraft, automotive and automotive parts to really understand the art of interiors design, research and developing related to passenger comfort. In these companies we interviewed specialists in comfort, ergonomics and aircrafts and automotive interiors' designers and cabin and package engineers.

This prequel of actions allowed the team to be familiarized with the research theme, enabling us to build an activity library, in order to create research protocols to be used on commercial flight assays, as well as in mock-up, on the simulation of typical activities, which were six pre-determined tasks: reading, resting, using a notebook, writing, using IFE and having meals. We chose those specific activities, for they are the most frequently performed by passengers in commercial flights, in sitting position (position that passengers spend most of the time, when flying).

Stage 2 – Preparation

To prepare the research team, knowledge on corporality and bodily posture were studied, so as to render perception to the team, so everyone had an accurate level of perception as to posture, to disturbances, and their interaction during the course of events of the performed activities. The first step was the performing of assays on mock-up to prepare students to become aware of those aspects.

Simultaneously to those assays, protocols were created, with the defining of the variables to be controlled. Amongst them was the duration of each assay - 40‘ standard, excepting for writing which should last 10’, and meals with no

determined duration - ambient temperature (21ºC), relative humidity (50%). Besides that, with goal of changing leg spacing, we used a 33'(83,8 cm) pith, while in doubles assays we used a reduced space of 28'(71,1 cm). One should remind that the vibrational acoustics systems remained turned off on all assays for this article.

Stage 3 – Individual Activities' studies

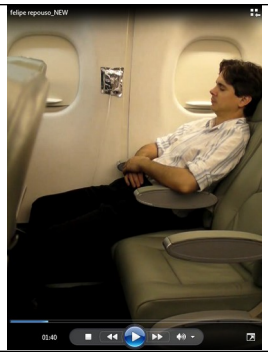
The first assays were intended to investigate how would be the performing of activities without a passenger sitting beside oneself, so those were the individual assays. In those assays there was always a user-researcher and an observer-researcher. The user-researcher performed predetermined tasks, whilst the observer-researcher took charge on positioning the camera, controlling time, making the video as well as taking notes of most significant postural changes, when did they happen, and all kind of observations on facial expressions related to the co-worker's comfort /discomfort.

Right after each assay, the observer should interview the user, in order to have a fresh account to register all sorts of impressions on the activity, its difficulties, disturbances, facilities and strategies for performance.

The following tasks of each participant were to elaborate a table for better understanding of the chain of events, with base on the notes made by the observer during the assay, video analysis and the fresh account. The result of this task is a table like the one on Table 1.

To conclude this cycle of analysis, the team had a meeting, to verify the common points of all assays, as well as the peculiarities in each way of using objects by the individuals. This way a posture library was buildt for every task, as well as a list of demands for each task, relating to the environment and the objects.

Table 1: Example of table used do analyze relationship about activities, posture and (dis)comfort in individual studies.

Time	Body positioning (image)	Posture description (attention to supports)	Postural change motivation (disturbance/pain)	Problems
01:40		Accommodating the legs.	I found a more relaxing position, with the right knee flexed in a 100º angle and the left one in an angle higher than 120º.	Had to maintain a one foot lowered in order not to kick the metallic box under the seat in front.

Stage 4 – Couple Activities' studies

To complement data on individual assays, there followed doubles assays, for there still was missing information on space restrictions - how it would affect users' (dis)comfort when performing their varied tasks with reduced space. So in addition to creating a protocol for two passengers siting side-by-side, sharing a central arm support, the regular space for legs was reduced to a 28' pitch. Due to technical restrictions we weren't able to perform IFE (In-Flight Entertainment) during those assays.

With the goal of achieving as most data as possible and better controlling variables, tasks of reading, resting and notebook using were performed by users in turns, so no task was performed simultaneously by both users - always lasting 40' a alternately, so as to mix as much as possible the inter-personal variables, including alternating of window/corridor positioning. On the other hand, writing task was performed in 10'assays, simultaneously, as well as meals with no duration restriction.

Analysis of doubles assays followed the same criteria of individual ones, so each researcher was responsible for elaborating his personal table of analysis with use of images from the videos, for better understanding of the course of action.

Table 2: Example of table used to analyze relationship about activities, posture and (dis)comfort in couple studies.

Time	Body positioning (image)	Posture description (attention to supports)	Postural change motivation (disturbance/pain)	Problems
13:31		I stretched myself and massaged my tensioned neck	Cervical disturbance	One must keep the neck flexed and lower the head and to the front to visualize what's on the screeen, for it is too far and low.

Stage 5 – Relationship between activities and objects for ideas and solutions

After the doubles assays, several meetings were made to compare results of individual and double assays, besides establishing relations amongst all activities and used objects. Also we succeeded in establishing paramenters of needs to each activity, as well as to raise difficulties, facilities and common strategies.

With base on all these analysis, it became possible establishing relations amongst all activities, thier needs and what objects are no longer used in every task. This relation may be visualized in Table 3 VERIFICAR NUMERACIÓN in the Studies and Results section.

The closing meeting for this stage was a brainstorming session, so participants could present ideas to solve the detected problems.

Stage 6 – Design, Innovation and Handbook creation

With base on the previous brainstorming session, a parameters guide was built, in which criteria for future projects were established. Unlike most manuals, this guide will not present physical measures as reference to a project; it does present all needs that were detected, and suggests designs for new artifacts that may render affordance of new sorts of activities, so users may maintain less damaging postures as well as adjust devices to their needs.

Based on this guide, new objects proposals are in course, with use of computer assisted designing and virtual simulation with use of mannequins 3D, which allow positioning virtual users in typical postures, so as to verify whether spacing is compatible with the suggested activities.

STUDIES AND RESULTS

Assays in commercial flights had some restrictions due to sharing space with passengers and having reduced space to place the tripod for the camera. Despite those restrictions, the performing of air travels in several aircraft models allowed comparison between their configurations, advantages and disadvantages

The assays performed at the mock-up could be done according to the previously established protocols, described in the session refering to all methods and protocols. They allowed the gathering of very interesting informations, to elaborate the matrix of correlation of activities and objects, illustrated in table 2.

This table was built with the aim of establishing relations between the frequency of use and the importance they have for the activities. With this, we expect to help engineering teams to establish relations during the developing of projects, with simulations of the several positions adopted during activities, and designing of objects that promote a better use of the restricted available space, as well as more comfort for future users.

Table 3: Matrix table of relationship between activities and objects.

	Object	Activity					
		Reading	Resting	Writing	Noteboo	Meals	IFE
Seat	Seat						
	Seat						
	Head						
	Lateral						
	Central arms						
Accessories	Table						
	Floor/						
Spacing/ Covering	Spacing between						
	Side wall						
	Corridor						
Environment adjustings	Reading						
	General						
	Adjustabl						
	Distribut						

Caption with levels of influence of the object on the activity/ interaction of the user with	
Indifferent	
Little	
Medium	

The suggested method allowed analyzing relations between several activities experienced by passengers in aircrafts cabins, and environments and objects design. Also this work allowed the creating of a typical postures library for each one of the activities. These informations may help in the designing of new projects for objects and environments, with better results under comfort, affordance and usability points of view.

DISCUSSION AND CONCLUSION

The subject (dis)comfort has still much to be explored. Its theoretical models, methods and tools are still evolving. The difficulty in quantifying something highly subjective, and under diverse factors, makes it extremely hard to obtain accurate information on comfort and discomfort of users, products and environments.

This articles' proposed method uses qualitative information and intends deeper action, distinguishing itself from most existing methods, that use quantitative data, with a qualitative approach, in order to give meaning to values obtained with the use of tools as surveys and interface pressure mapping, to establish correlations between the numbers obtained and users' opinions. Therefore, having the goal of acting in depth, this method will not allow a large-scale information achievement, on users' opinions. Since other methods allow obtaining that kind of information, this one is intended for obtaining details that haven't been approached so far.

Since the realization of this project allowed, rendering a whole research team in obtaining positive results as to the gendering of ideas for the creation of new solutions, we believe this method may assist designers' teams in project activity. Being so, we hope this method will be used in the training of project teams, stimulating their perception, and so obtaining better results in new product designs and environments, with more comfort, usability and affordance

ACKNOWLEDGEMENTS

This paper is the result of a joint work, being necessary to thank everyone involved in The integrated project "Cabin Comfort and Design – Integrated Analysis and Development of Criteria for Comfort", and all those who helped directly or indirectly for the attainment results here exposed. Special thanks to Ximena Mujica, for helping in translation to English.

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