Participatory approach to draw ergonomic criteria for window design

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Abstract

This paper sets new criteria to improve windows design strategies using participatory ergonomics and the grounded theory method. Focus groups are used to investigate participants' reactions and discussions about the visual stimuli and their deduction in terms of further employment of specific window design techniques or uses. Results framework are established through the relevance of the relationship between 25 coded categories, grouped in 5 main macro-categories used to describe the value attribution of ergonomic window design from the users' perspective. Three design principles are highlighted: connection with the outside context to feel oriented, filtering glaze or techniques to mediate the outdoor stimuli towards the ideal indoor conditions, and manageability. Overall the method is validated and applicable to other architectural features design study. For the designer or professional working on innovation and production in the Architecture and Engineering industries, these principles could be an efficient tool to improve the industrial appealability of a product.

Keywords: Focus Group; Ergonomic Product Design; Sustainable Product Design; User-centered Design; Collaborative Design.

Total number of words: 7019

1. Introduction

A window is the fundamental component of the habitation, allowing visual and physical connection between outdoor and indoor environments. For example, it is useful to protect the indoor space from significant environmental and climate changes and allow natural air ventilation, providing comfort for the occupants of the building. Lately, human perception and ergonomics have become of increasing interest when developing new architectural and engineering design systems.(Fusaro et al., 2018) For this aim, the need has intensified for new research methodology to make the architecture as adaptive and dynamic as possible.(Del Grosso and Basso, 2010) This also means to move the aim of the design from an enterprise-centred to a costumer-centred perspective, with a deeper focus into the user values which describe also emotional values. (Singh and Tandon, 2016; Wang and Zhou, 2020) These refer to operational benefits of a product which include but are not limited to attachment and pleasure or fun.(Dianat et al., 2016; Tang et al., 2020) External inputs, indoor comfort needs, and ergonomics have become a fundamental part of the design innovation process. (Köhler et al., 2017; Nagamachi, 1995a; Pereira Pessôa and Jauregui Becker, 2020; Seim and Broberg, 2010; Singh and Tandon, 2016), however, published work on the "Construction" and architecture fields is still limited.(Joshi and Deshpande, 2019) Window design is an excellent example of this phenomenon and, to accomplish this task (Kang, 2006), it has been continuously improved during different ages, culminating in a significant technological revolution during the twentieth century. The first documented attempt of technological improvement of the window system was made by Yakutians in Balagian dwellings (Rem Koolhaas, 2014) (1910). In the following periods, the continuous structural innovations from occidental Engineering were accompanied by a careful study on new optimisation of window technologies for ventilation and insulation (thermal and acoustic) involving a series of new materials(Kang, 2006), active or passive strategies(Huang et al., 2011), and set up techniques(Asdrubali and Buratti, 2005). Looking at window technology scenarios, most contemporary researchers use physical simulations or psych based parameters to evaluate the impact of architectural features on people's lives (Fusaro et al., 2020, 2018). Of course, these methodologies can count on established guidelines (Harvie-Clark et al., 2019; Zwicker and Fastl, 1999) which are useful to validate the results and this is so far an efficient solution; However, there is still need of better understanding the interactions between people and windows in order to optimise building system performance and the human well-being through architectural and engineering design.

Participatory ergonomics can be useful for such a research gap, as it actively involves the users in implementing ergonomic knowledge and procedures in the environments they are used to.(Nagamachi, 1995b; Naweed et al., 2018; Tang et al., 2020) This users' effort is supported by a leading investigator to improve their living and working conditions and the product quality. Generically, participatory methods have been widely used in social studies related to urban, architectural and engineering design. (de Guimarães et al., 2015; Garrigou et al., 1995; Xiao et al., 2018) Specifically, participatory methods such as focus groups have been applied since the '30s (Morgan, 1997), and they have become popular for business based study(Barbour, 2007) (e.g. to develop a new product, improving an existing one or for their promotion). This method involves the main theme discussion between a group of people gathering together and exposing them to explicitly set inputs (Mcdonagh-philp Mied and Bruseberg, 2000), culminating in a final part of collaborative design. (Kim and Lee, 2016) This collaborative design part can be largely used in participatory ergonomics, which starts by organising a project team to solve the ergonomic problems in selected environments. People who join the participatory ergonomics team are highly motivated by their participation in identifying human factors in familiar environments and finding solutions to problems. (Bridger, 2003; Dianat et al., 2016) The users know very well what kind of ergonomic problems there are in the environments they live and work in every day, and they become eager to solve them in terms of ergonomics. Therefore, they are willing to receive the redesigned environmental system, because they have participated in redesigning it and reforming their organisation for themselves and future generations. (Pitt and Shew, 2012) Moreover, to analyse the data gathered through participatory methods, they have been frequently combined with another social science method named 'grounded theory' (GT)(Glaser and Strauss, 1967), which uses an inductive iterative approach to construct a theory.

This system, invented by Glaser et Al.(Glaser and Strauss, 1967) (1967), is primarily used to analyse the qualitative data systematically, or "Discovering from the data" as its author used to define it. Through the continuous reinterpretation of data and addition of information, the GT uses an inductive iterative approach to construct a theory. Data might be gathered by interviews and field observations. However, other sources such as focus group transcripts, reflective journals, questionnaires, and policy documents provide additional information in the form of elicited (data are written by the research participants) and extant texts (data existing independently from the research). (Charmaz, 2006) They are coded by specific properties and characteristics (dimensions), which reflects the emerging patterns from the analysis(Charmaz, 2006; Glaser and Strauss, 1967). Once the categories' connections are saturated, the final phase of selective coding can be conducted (Corbin et al., 2008). In this phase, themes relevant to the description of the phenomenon are individuated and connected with the core category of the theory (more details on this procedure can be found in Sections 2 and 3.1). Generally, focus group and GT method has been involved in design studies only a limited number of times (Mcdonagh-philp Mied and Bruseberg, 2000), and never for window design. This disconnection has led to a product which does not consider how people possibly relate different window shapes, materials, or mechanisms with the indoor and outdoor environmental function and the degree of privacy. For this reason, it is necessary to fill this gap to improve the ergonomics of this fundamental tool.

Therefore, this study aims to code human awareness of window design value attribution to derive new ergonomic designing criteria and principles. These principles should hierarchically explain window characterisation in order to improve the overall comfort and make the design more functionally active. This process passes through the designed topic guide and the data gathered by the focus groups, then the GT data elaboration. Such a methodology might become useful for engineering and architecture researchers. It could be applied to other building features to seek a more in-depth definition of users based design according to different environments or participants' background. Moreover, the final principles derived could lead to a specific investigative path for those designers who want to improve window construction with a more ergonomic approach. (Kuorinka, 1997) They could help to design optimal window system from the users' perspective, for both engineers and architects, improving indoor comfort and product satisfaction.

2. Methodology

The study aims to investigate the advantages and problematic aspects of window design experienced by general users, to understand its impact on the indoor comfort and people behaviours, and so to optimise the ergonomic design process. Following the focus group method, visual stimuli were set at the beginning as well as a topic guide. The Focus Group method was used to facilitate a discussion about generic life scenarios involving the presence of a window system. Visual examples supported the single and collective awareness of window design influence on comfort perception. Participants were sought between the University's staff and students as well as people residing in Sheffield. A total of five focus groups were organised and performed in one of the University buildings. For each focus group, 12 tasks were assigned and completed, while the related visual stimuli were shown, according to the topic guide. The focus group method was more appropriate than individual questionnaires(Deininger et al., 2019), since the awareness of the group more than just of the single person was one of the critical points for the research questions. Indeed, this methodology was concerned about whether people relate actively or passively with window design, how they perceive windows as means of communication between outdoor and indoor environments, and how they think that this feature could be improved to create a better indoor environment.

After data were collected, GT was used to analyse them. Generally, during this phase, the information was separated into smaller chunks, through a word-by-word or line-by-line process called open coding(Charmaz, 2006). A constant comparison method is indeed at the core of GT, which requires new codes to be compared to those already defined (like in our focus group study settings) or identified (along with the data analysis) focusing on similarities and differences. The theory of continuous refinement was ensured by the constant reorganisation and redefinition of the thematic categories used for the emerging of the theoretical constructs(Charmaz, 2006). After having identified significant themes, the connections between categories in different parts of the data were explored in the so-called axial coding(Corbin et al., 2008), where their significance to the whole body of data was discussed. At the end of this study, 25 categories and 5 macro categories were elicited through GT. Moreover, three principles which drive the value attribution of ergonomic window design from the user's perspective were identified. Figure 1 shows the study workflow describing the passages between the initial settings, the processing, and the results.

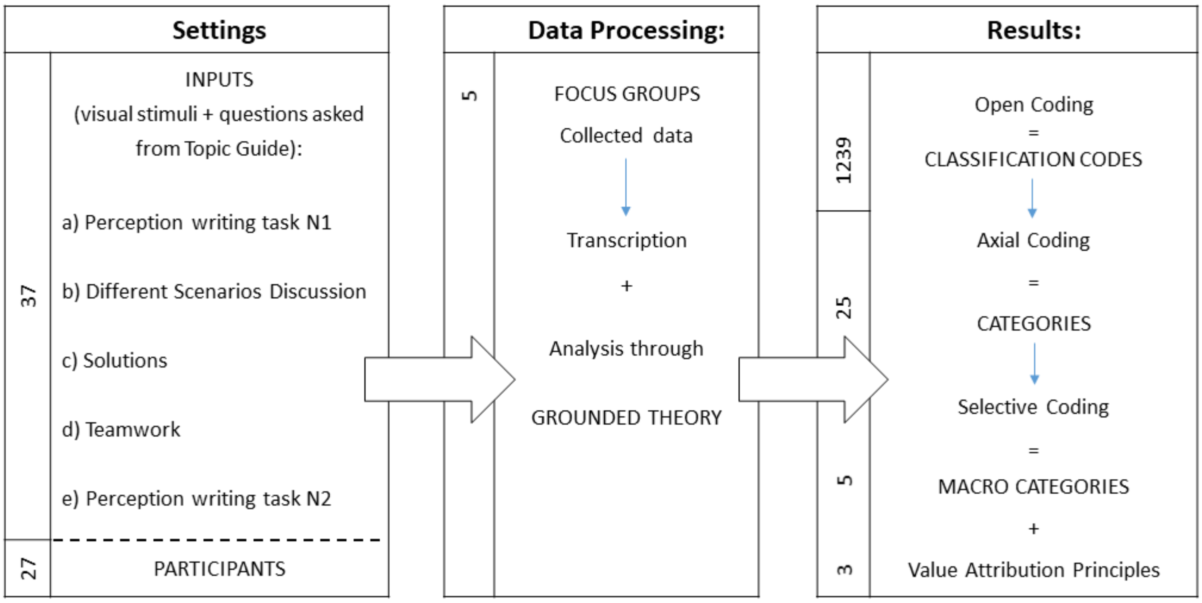

Figure 1 Study Workflow describing the passages between the initial settings, the data processing, and the results (the numbers indicate the elements used or elicited for each passage).

2.1 Procedure and questions asked

The procedure that was followed to gather the data from the focus groups was entirely designed from scratch. The material used, as explained above, was a visual stimulus to start the discussion. As shown in Figure 2, the definition of passive and active role from the participants' perspective was drawn first to receive and process several pieces of information (passive role), and then discuss their opinion and elaborate as a group an ideal window design (active role). All the participants faced the same passive and active experimental parts at the same time, and this did not favour any member of the group compared to others. The experiment consisted of six parts:

0. Presentation of the study named 'Focus group: the relationship between spaces and openings experienced', consent form, and presentation of the participants to each other;
1. Negative/positive perceptions about window design expressed individually (written form): It was asked to the participants to write what they perceived as being potentially negative or problematic and positive or beneficial about windows. This exercise was also repeated at the end of each focus group to understand

if and how the study affected the way participants perceived the indoor environments depending on window design.

2. 'Different scenarios discussion': images of different contexts and different windows typology were presented to the participants, to make them discuss it and highlight the actual knowledge and awareness on window design strategies owned by each of them. For instance, they were keen on explaining how they perceive the intensity of the light, the dimensions of the openings and other similar characteristics. The scenarios were set to define offices (Figure 3,a-c), street views and spare time contexts (Figure 3,d-f) or home environments (Figure 3,g-i). The first part of this second stage was used to give the participants a universal base of the technical definition of different window's designable characteristics (parts or typologies) and different window design options. This stage defined as 'passive' helped them to create their vocabulary and strengthen their awareness regarding such aspects of window design to support their argumentations in the following parts of the study.
3. 'Solutions' phase: new images were shown to the participants to represent different methods that might have been used to solve some of the problems highlighted at the 'Different scenarios discussion' phase. This part, categorised as 'active', focused on observing the group's problem-solving techniques both individually and collectively. The participants examined several methods in order to mediate the connection between the indoor and the outdoor environment in terms of visual contact, lightning, acoustics and thermal transmission, using the shapes of the opening, window's structure, and glaze treatments. As it is clear from the figures shown in the previous section, those methods were grouped depending on different shapes (Figure 3,j-k), overglaze printing (Figure 3,n-o), blurring (Figure 3,l), opaque (Figure 3,m), blinding and brises solei systems (Figure 3,p), reflective or mirror glaze (Figure 3,q-s), and coloured filters (Figure 3,t-v). After observing these pictures, the participants spotted different perceptive key points and discussed the feasibility and effectiveness of each solution systems.
4. 'Teamwork': a series of windows characteristics (Shape of the opening, Window inclusion or extrusion respectively to the wall, Frame thickness, Glaze opacity, Pane division) were presented to the participants through different systematic representations, with two, three or four options for each characteristic. They had to face a collaborative design stage(Adelson, 1999; Kim and Lee, 2016), choosing a single option for every category step. The aim was defining a prototype of ideal window design through discussions and argumentations about their reasons, sometimes mediating their preferences and in the end, finding compromises. The explicit formulation of the questions asked to guide the participants in the discussion, made them even realise the importance of these two separate stages, and helped them to follow a clear structure of the debate. In this fifth and more active stage, the options within the categories that participants had to choose collectively were:
   1. Shape of the openings: *rectangular - square - circular - polygon;*
   2. Window inclusion or extrusion respectively to the wall: *included - extruded;*
   3. Frame thickness: *minimal - thin - thick*;
   4. Glaze opacity: *transparent - slightly opaque - strongly opaque;*
   5. Pane division: *any - single - multiple.*

   At the end of this exercise, the window design that resulted from their decisions was shown to make them understand the importance and the real effect of each characteristic's combination. These were not a mere picking up or exclusion doing exercise but, after the previous information absorbing and brainstorming stage, it resulted as the expression in which all the window design awareness of the individuals and the group were condensed.

5. As at the beginning of the study, in the final part, the participants were asked to express if their perception of negative and positive window's aspects was changed and if their awareness of window design strategies was being affected somehow by this study. The majority of the participants (70%) were positive on the influence of the experiment on their self-awareness on window design relationship and gave their feedback in written form.

Figure 2 shows the different parts of the study with their participants' engagement level (=P.E.L., active 'A' or passive 'P', which was the same for every participant in every phase), the purposes and the responsivity percentage of them (R%):

STUDY PARTS	P.E.L.	PURPOSES	R%
1. Perception writing task N1	A	Unconditioned perception of window's elements, characteristics, or presence	100%
2. Different Scenarios Discussion Work environment; Spare time activities in public and private places; Home environment	P	Raising of problematics related to different environments: private/public, exposed/non-exposed, crowded/lonely	90%
3. Solutions Different shapes; Blurred or opaque glaze; Over glaze printing; Brise soleil, Reflective glaze, or Mirror glaze; Coloured glaze or Filters	P	Giving possible solutions to the problematics raised in the previews part Setting common homogeneous knowledge and vocabulary regarding window design	80%
4. Teamwork Shape of the openings; Window inclusion or extrusion respectively to the wall; Frame thickness; Glaze opacity; Pane division	A	Discussion of the options and group choice of one option to be used in the final prototype	80%
5. Perception writing task N2	A	Perception of window influenced by the study process	70%

Figure 2 Study parts with relative participants' engagement level (=P.E.L., active 'A' or passive 'P'), the purposes, and the responsivity percentage of them (R%)

2.2 Setting of the visual stimuli

The methodology used for this study derives from Focus Group method, where different typologies of users discuss together undergoing the same tasks in an informal environment, raising questions and problems regarding the specific themes proposed, and supervised by a moderator. (Mcdonagh-philp Mied and Bruseberg, 2000)
The two core parts of this study were: (1) observing the reactions of the participants to different scenarios, and (2) understanding which strategies the participants would adopt to bring the indoor environment to an optimal setting. It was necessary to set a topic guide(Barbour, 2007) to define key terminology better and help the communication between the participants. The guide defined all the different stages of the study in terms of active and passive participant roles and organised visual stimuli (representing the *a Priori* Limited Knowledge(Barbour, 2007)). It is important to stress again that all the participants experienced the same passive and active tasks at the same time, without favouring any member of the group compared to others.
The *a Priori Limited Knowledge* to guide the focus group in both parts (1) and (2) was presented in the form of visual stimuli. A number of 21 pictures of different indoor and outdoor scenarios including the feature window were used for this scope. The main aim of this visual stimuli was to give the participants information about specific window's parts terminology and characteristics, following design concept modules (such as indoor function, outdoor connection, and others that will be presented in Section 2.4 *Categories Framework*) and considering which aspects customers prefer to have a voice in. (Veenstra et al., 2006) set a homogeneous basic knowledge to give to all the participants the same possibility to discuss their ideas on window design. Moreover, through the use of *a Priori Limited Knowledge,* it was possible to achieve a structured and linked beginning of the discussion. With this method, all the categories are defined and connected following the researcher criteria. Of course, since the focus group is a method of open possibilities nature, the list of categories defined in the topic guide had to be updated and expanded due to participant interaction and autonomous collective constructions. *A Priori Limited Knowledge* was appropriate for setting the study; however, GT was introduced in the analysis part, in order to define the window's qualification categories from the group discussion, added then to the topic guide for the sake of completeness.
More than reaching consensus or decision, this mixed methodology aimed to investigate issues within a priori limited knowledge. Since an individual's opinion related to issues can change during the discussion, it was fundamental for the researcher to focus on how the perspective changed and why it did. Because of this, even if individually the figures shown were limited under many aspects (such as outdoor scenarios, different light conditions, etc.), they were chosen for their simplicity of input. The number of elements and number of dominant window design characteristics were contained, and all together, the pictures gave overall complete information about window's components and scenarios. In Figure 3, all the pictures involved in the study are presented. They show different scenarios with a significant amount of characteristics that the participants could use for each different study stages. With these instruments, a fairer discussion was guaranteed, especially when during the teamwork phase (the one for constructing the ideal window design), the group managed to accomplish the task with less help as possible from the moderator. For this reason, this was evaluated as an effective mixed methodology.

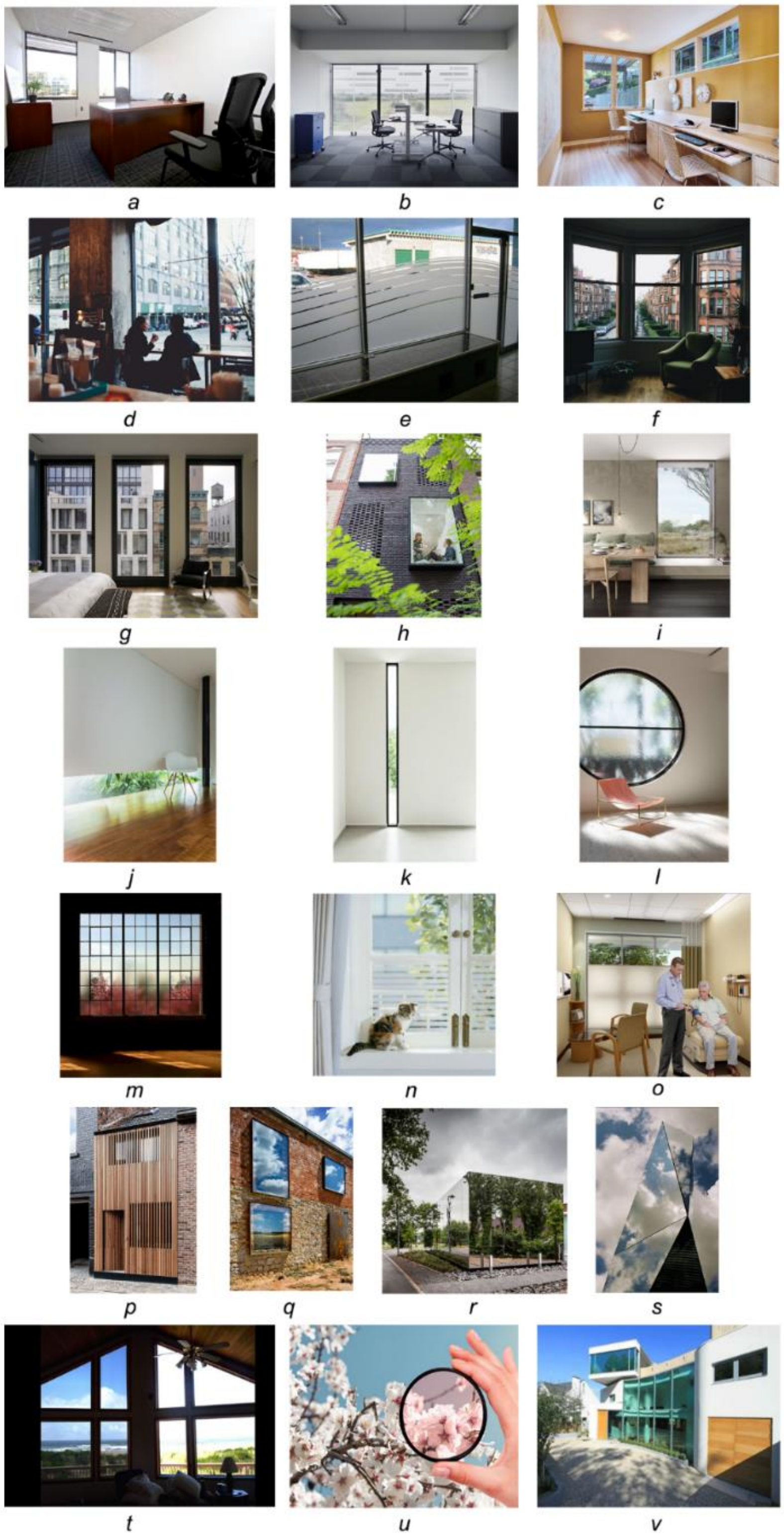

Figure 3: Different Scenarios Discussion figures: offices (a, b, c), spare time contexts (d, e, f), home environments (g, h, i); and Different Solutions Discussion figures: different shapes (j, k), blurring systems (l), opaque systems (m), overglaze printing (n, o), blinding and brises solei systems (p), reflective or mirror glaze (q, r, s), coloured filters (t, u, v)

2.3 Participants

The recruitment was done through the University of Sheffield students and staff, and Sheffield's residents. The sample for the study was set as optimal with 5/6 participants per group(Barbour, 2007), and the number of focus groups was retained as enough, once the data gathered were saturated(Morgan, 1997).
The whole group of participants included 27 individuals of which 20 females and 7 males, with age between 24 and 44 years old, hailing from Europe and North Africa (33%), Asia (45%), and America (22%). It is essential to highlight that the study focused on the different backgrounds which would have defined correspondent factors under contextual experience (such as demographical, space usage and psychological). (Dokmeci Yorukoglu and Kang, 2017) Hence, window design investigation is still at a global environmental stage in terms of history/heritage, ethnicity, geography and economic situation.
Moreover, to make the methodology as effective as possible, it was fundamental to have a moderator to guide the discussion without influencing it, checking and putting the discussion back on the main topic when the participants started to deviate from it.
In the following graphs (Figure 4,a-d) is possible to observe the participants' characteristics in terms of gender, age, and nationality.

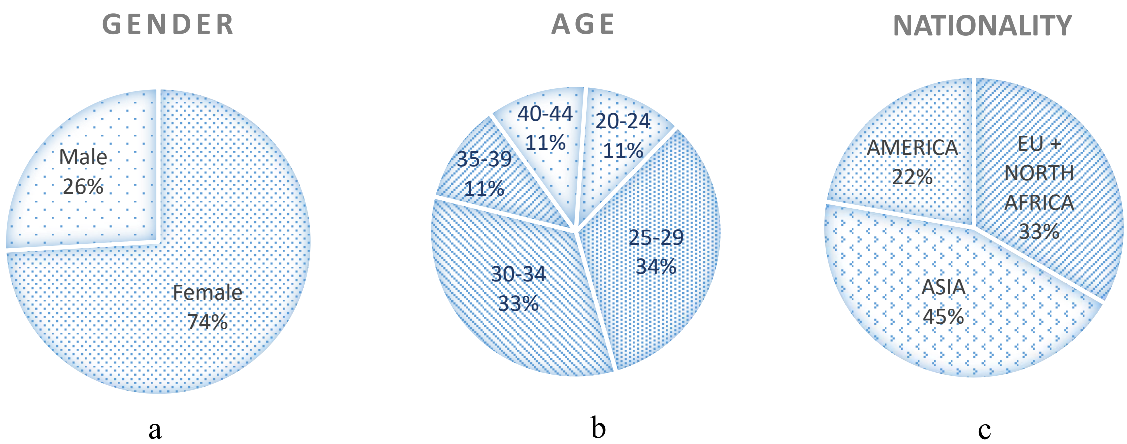

Figure 4 Background of the participants: (a) gender, (b) age, and (c) nationality.

2.4 Categories framework

During the analysis part, a categories framework was defined through a technique used frequently in qualitative research method: 'grounded theory' (GT). The GT aims to explain the processes characterising the observations collected rather than merely describe the phenomenon. The theoretical saturation and full development of the categories elicited from the choices of participants (which should account for minimum and maximum variability in the data), ensure the validity of the theory and states the end of the data collection(Charmaz, 2006; Corbin et al., 2008). The completeness and rigour of the study are more important than the number of focus groups or interviews conducted. The main influencing factor is represented by the presence and epistemological position of the researcher moderating the study. For these reasons, negative effects deriving from any personal bias were neutralised, and the only interference was related to strictly follow the topic guide in the specified amount of time. It was interesting to observe for each stage of the study at the transcript analysis stage, which specific keywords were used. Indeed, it can happen that beneath the overall discussion, some particular words get repeated by several participants and so become keywords. In this way, it was possible to group them in noticeable categories and observe how they were related to each other by the participants. Following Barbour theory (Barbour, 2007), it was also important not to go through the transcript analysis stage too far from the actual focus group, and then to read the transcripts while listening to the original recording. This procedure allows the researcher itself to recall as much as possible of the discussion, especially noting any significant peaks and expressions of participants voices. The coding frame started from setting the *a priori* knowledge and was expanded during the analysis, incorporating GT themes introduced by the participants' discussions. So, from the set *a priori* knowledge, the first analysis categories were:

a. Indoor function, when the participants reflected on a specific function of the indoor space;
b. Outdoor Connection, when they focused on the importance of the various outdoor scenarios;
c. Time amount of use, related to a particular long or short term activity influencing the evaluation of the window design;
d. Frame shape;
e. Inclusion or extrusion off the wall;
f. Frame thickness;
g. Glaze treatment, intended as any possible colour or filtering, mirroring or reflective, blurring or opaque, overglaze printed and screening variation;
h. Panel division;
i. Wideness of the opening;
j. Blinding system;

These categories had been defined so to be applied to each relevant point raised from the topic guide. Moreover, during the analysis, the GT coding added new categories and the relative belonging to different context group (or macro-categories), elicited from the open, axial, and selective coding (showed in the results section).

At the end of the analysis stage, 25 categories and 5 macro categories were coded. Even if this is part of the analysis stage, it can be considered a fundamental achievement for the methodology itself. So it is included and fully explained in the results part.

3. Results

3.1 Categories' properties and dimension determined through Open Coding

After the verbatim transcription of the focus groups' audio recording, the software NVivo Pro 11 for qualitative research was used to code the files. The researcher broke down the data in chunks, examining, comparing, conceptualising, and categorising the emergent concepts. The first phase, called open coding, consisted of the analysis of the text line by line focusing on the mental constructs and the vocabulary related to it. Contemporary the objective and reflective sphere of their expressions were evaluated to understand the participants' views on the relationship they had with window design, and the possible improvement on the already known window system. A total number of 1239 classification codes were used to determine the Window Design categories by properties and dimensions qualitatively. In Table 1, an example of open coding workflow is showed. In some cases, the chunks of statements could be coded in two separate parts, and different categories would have derived.

Table 1 Example of open coding workflow with relative processing parts: Statement, Chunks, Codes, Categories, Dimensions

Statement	Chunks	Codes	Categories: properties	Dimensions
They have different functions: the one on the right (Figure 3,o) needs to be fully private because there is some medical stuff happening and the one on the left (Figure 3,n) it just gives you enough privacy so people can see what you are doing but not clearly.	They have different functions:	functions	Indoor Functions	range
	the one on the right (Figure 3,o) needs to be fully private because there is some medical stuff happening	privacy	Degree of privacy	high
		medical use	Indoor Functions	defined
	and the one on the left (Figure 3,n) it just gives you enough privacy	privacy	Degree of privacy	sufficient
	so people can see what you are doing but not clearly.	outdoor relationship	Outdoor Connection	possible neglectable
			Effectiveness	small
I think the bottom one (Figure 3,f) is the only one we choose so we can have some control on it. We can open it for some ventilation.	I think the bottom one (Figure 3,f) is the only one we choose so we can have some control on it.	control	Manageability	good
	We can open it for some ventilation.	control	Manageability	good
		outdoor relationship	Outdoor Connection	possible
Maybe in my country for example this type of window would work, in contrast with the UK, because the thermal comfort is important as the privacy. So we need this type of design (Figure 3,k)."	Maybe in my country for example this type of window would work,	functionality	Life Experience Connection	direct
	in contrast with the UK,	comparison	Life Experience Connection	direct
	because the thermal comfort is important as the privacy.	comfort	Amount of Lighting	good
		privacy	Degree of Privacy	high
	So we need this type of design (Figure 3,k).	usefulness	Frame Shape	necessary

The additional categories and the determination criteria were:

a. Floor height;

b. Degree of Privacy, observing how much a specific characteristic of the window design changed the perception of being observed or not from the outside and how comfortable or uncomfortable this made the participants feel about;

c. Costs, considering participants concerns on the window maintenance and effort;

d. Effectiveness, meaning how significantly supportive was the window design towards the ideal indoor comfort condition;

e. Life Experience Connection, coded when the participants related a specific window characteristic to a direct/indirect experienced or known/studied condition;

f. Manageability, when the participants expressed a particular comment related to the window design control;

g. Amount of lighting;

h. Comfort;

i. Safety, coded when the participants related a part of the window design or a qualitative configuration as creating a safe environment or not;

j. Anxiety, considering the relation of some windows characteristics to stressing situations;

k. Ventilation;

l. Design;

m. Listening, elicited when participants expressed the specific will to have a connection with the outdoor environment in a sonic way;

n. View;

o. Architecture.

3.2 Categories connection through Axial Coding

After the preliminary coding, closer attention was paid to those categories which were recurring during the text. With an increased level of organisation, the categories were studied and divided depending on their dimensions and properties. As Glaser et al. (Glaser and Strauss, 1967) indicate, to be efficient, the analysis had to be done "around one category at a time in terms of the paradigm items". In the axial coding, this category becomes the reference axis concerning which other categories building is performed. Figure 5 shows a schematic of the axial coding, explaining the connections between the 25 elicited categories. The size of the name font represents the importance of each category in terms of spoken iterations number.

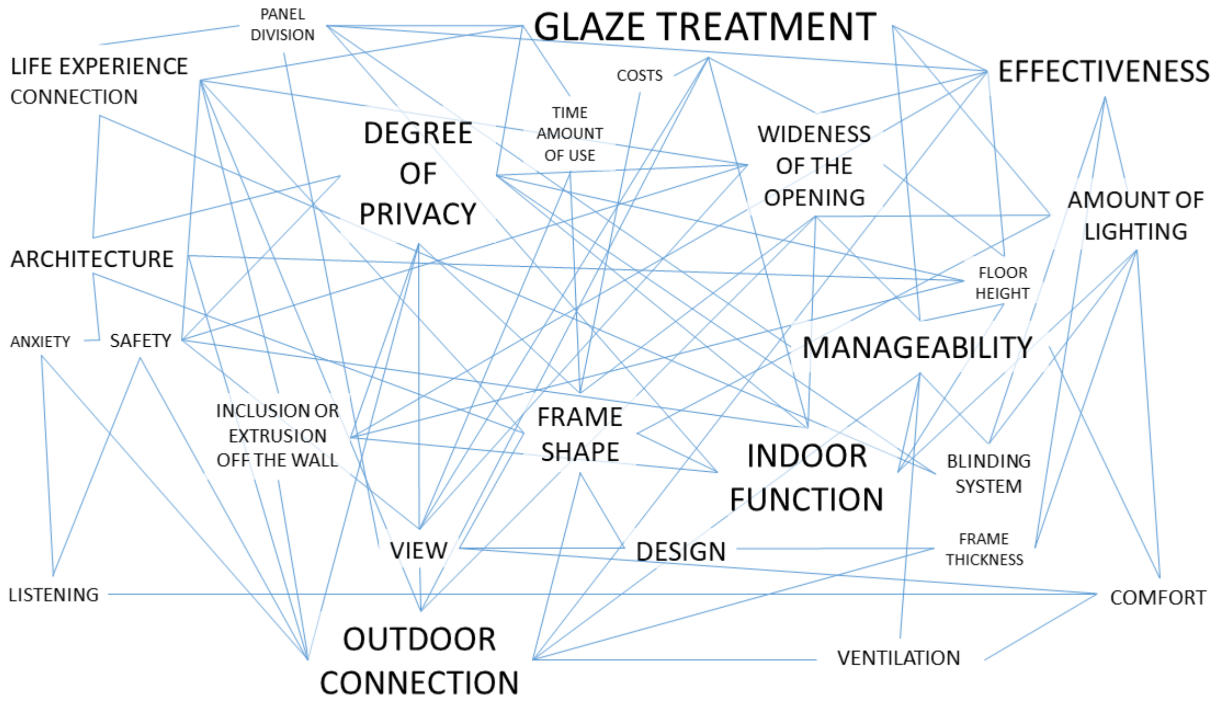

Figure 5 Schematic of axial coding phase with the macro-level categories connection

3.3 Definition of Value Attribution of Ergonomic Window Design from the users' perspective with Selective Coding

The participants perceived the window design, whose aspects are positive or negative for their judgmental system, and how they would like to be entitled to modify what is not optimal. The topic guide and the visual stimuli were found very useful in this stage. Indeed, the categories already identified helped the participants to support their discussions. While, from the topic guide structure, they managed to explore new categories elaborated autonomously by the groups. After the axial coding defined the connections between the elicited categories and their relevance in the focus groups discussions, selective coding was applied.

This individuated and connected themes relevant to the description of the central phenomenon (in this case represented by the value of ergonomic window design from the users' perspective). This is identified as the core category of the theory and can be connected with all the other ones. The 25 categories were assigned to five macro-categories (see Table 2): Affective Impact, Contextualisation, Filtering Outdoor Stimuli, Manageability, and Architectural Inclusion. Figure 6 represents how the macro-categories are related to each other and which principles the users followed to establish the core category: Value of Window Design. This was defined by the participants through relationships highlighting 1) Importance of the Outdoor Connection to feel oriented, 2) Filtering the information from the outdoor without changing the meaning of it, and 3) Controlling the window system behaviours within physical boundaries. These three principles have been found at the base of all the focus groups discussions of the study, and they are fundamental for the Value of Window Design from the participants' perspective. Researchers and designers could use them when investigating window design optimisation or when trying to improve the engineering proposal towards window purchasers or selectors in the market.

Table 2 Categories and Macro Categories from the codes that describe qualitatively the Window Design

ERGONOMIC WINDOW DESIGN				
AFFECTIVE IMPACT	**CONTEXTUALISATION**	**FILTERING OUTDOOR STIMULI**	**MANAGEABILITY**	**ARCHITECTURAL INCLUSION**
Outdoor Connection		Glaze treatment	Manageability	Frame Shape
Degree of Privacy	Indoor function	Amount of lighting	Effectiveness	Design
Life Experience Connection	View	Wideness of the opening	Time amount of use	Inclusion or extrusion off the wall
Safety	Blinding system		Costs	Frame thickness
Anxiety	Architecture	Panel division	Ventilation	
Comfort	Listening		Floor height	

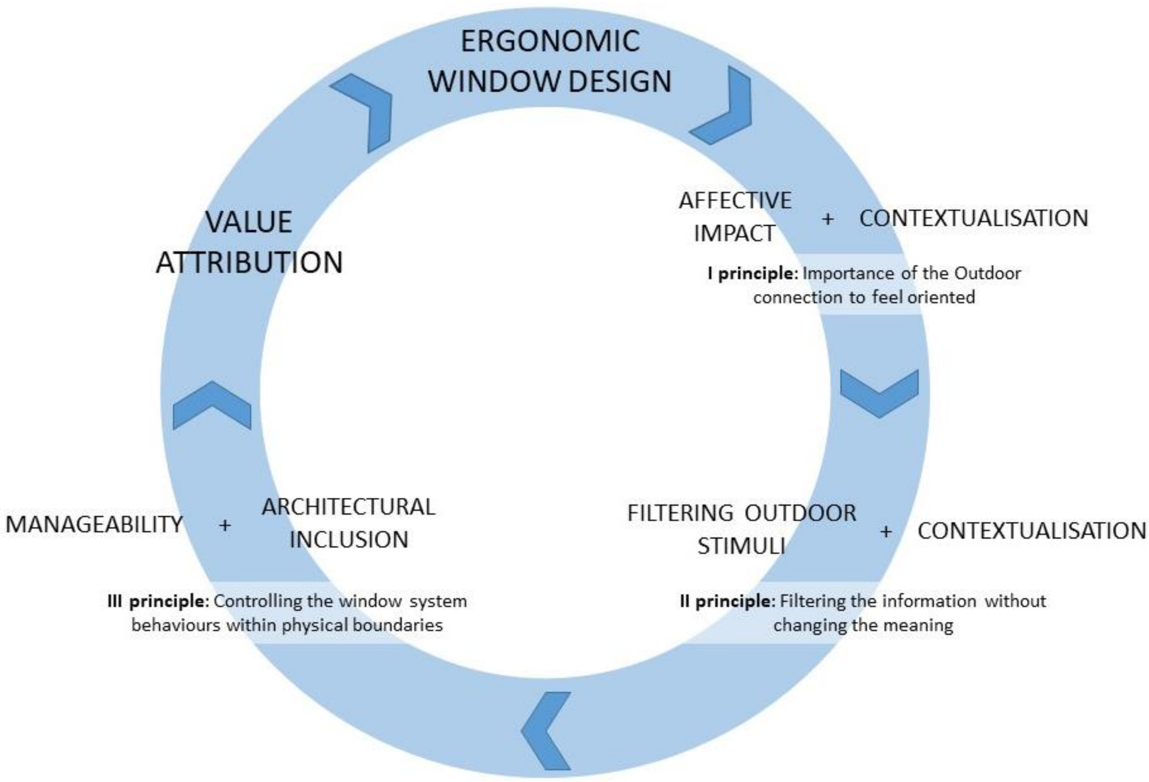

Figure 6 The attribution of value to Ergonomic Window Design built from by the relationships between macro-categories and their three fundamental principles.

4. Discussion

In this section, alongside an explanation of their theoretical and practical potential, the importance of the relationship between particular macro-categories and the three fundamental principles that drive them towards the Value of Ergonomic Window Design (from the participants' perspective) is further discussed with the available Industrial Ergonomics literature (Naweed et al., 2018; Pereira Pessôa and Jauregui Becker, 2020; Realyvásquez-Vargas et al., 2018; Shankar et al., 2020; Singh and Tandon, 2016; Wang and Zhou, 2020; Zhou et al., 2016). The importance of the relationships between the elicited macro-categories is underlined once more to highlight the significant impact of the principles they follow within the whole focus group experiment. The workflow coding supports this discussion (see Table 2 and Figure 6) and examples of focus groups excerpts (presented in the Tables 3-5) expressing the degree of interest and the emphasis used by participants to support and argue their ideas.

4.1 AFFECTIVE IMPACT and CONTEXTUALISATION: Importance of the Outdoor Connection to feel oriented

From Figure 5 and 6, it is possible to observe how the participants' need for contact with the outdoor nevertheless, the outdoor conditions could be non-optimal for indoor comfort. Frequently, such affective impacts and user's satisfaction over a specific design has been studied by researchers to develop a method to integrate the modelling attractiveness factors of productions based on user psychological needs (Singh and Tandon, 2016, as well as Wang and Zhou, 2020 for example). The first researchers established a list of values for the evaluation model including 'emotional values' such as Inspiration, Joy, Belongings, Care, Concern, Fun, Culture, Ease. Within our study, a series of categories and their properties that reflect those emotional values have been coded. Through them, the

'Affective Impact and the Contextualisation' principle was determined. The second researchers presented interval hesitation time value as a key factor for users' satisfaction when investigating and developing a product design system. Differently from Wang and Zhou, in our study, a series of auto determining factors such as those described within the categories and macro-categories (see Table 2) were considered to attribute value to the window design by the users themselves in a collaborative constructive environment. Here indeed, a focus group approach is at the base of a method that can serve researchers or designers to reach a more comprehensive analysis related to an architectural feature or product such as a window. A series of excerpts from participants' discussions now follow to highlight how the auto determining collaborative approach adds meaning to the principle of being affectively impacted by a window design and the importance of the outdoor connection to feel oriented.

Table 3 Statements from the Focus Groups Discussion to support the Discussion on the first principle: AFFECTIVE IMPACT and CONTEXTUALISATION

	Statements from the Focus Groups Discussions
a	"Even the view in front of me in Figure 3,c gives me some kind of privacy because it is like a private garden, but I'm just wondering if it was a street or if I can be seen from the outside, maybe is not going to be comfortable. However, being open to that view and being in contact with that relationship it will help me overcome the boring times.".
b	"Even if it is not a view that works. It helps me get oriented, and a part from the fact that such a light makes you feel tired, it's also the moment you want to look at the window and you can't, you won't think it at that time, but it's another factor that don't let go your mind and relax for maybe some moments…"
c	"I think very big advantage to have a window is to feel the outdoor so you can feel relaxed, and having this very narrow window it makes you feel the opposite, so you feel trapped in a place.".
d	: "because you know, windows are there to create a connection with life for me, this is how I feel in my home.";
e	"Honestly it is such a pleasure as it has the playful aspect, and I remember one man was just saying hello to people that were coming by. Moreover, you know looking at that playful childless aspect, and how they are using the windows like some kind of Connection rather than sitting on a plastic chair or the step at the porch, he is just at the window, not very high, but he looks relaxed and comfortable. So it is quite nice even though it was not designed for that.".

From *Different scenarios discussion* participants highlighted concepts like the statement in Table 1.a. *The Importance of the Outdoor Connection to feel oriented* has been defined by the participants also mediating the *Outdoor Connection* category with the *Degree of privacy, View, Comfort,* and some time with *Wideness of the opening*. This principle applied to window design helps the users to feel orientated and more aware of the outdoor situation in real time as you can see from the excerpts in Table 3.b,c. Overall, it is clear that for the users is essential to keep a connection with the surrounding outdoor environment even if sometime this would not maximise the comfort. They sporadically expressed this need, for example, in the *Teamwork* phase, by choice of one large panel completely transparent. This highlight the design *Effectiveness* and *Manageability* of the *Outdoor Connectio*n on the user's *Comfort* even through a *Life Experience Connection* as you can see from the statements in Table 3.d,e. Overall the principle of the *Importance of the Outdoor Connection to feel oriented* establishes a first guideline to the Value Attribution of ergonomic window design from users' perspective. It demonstrates the fact that the first approach of participants towards this architectural feature is concerning their subjective impressions of the indoor and outdoor context. From this point, in combination with the following principles, it is possible to define an accurate Value Attribution of the window design.

4.2 FILTERING OUTDOOR STIMULI and CONTEXTUALISATION: Filtering the information without changing the meaning

The window system represents a feature of connection between the outdoor and indoor physical conditions. The study's results seem to acquire even more functional value when associated with a variety of glaze treatments such as those presented in this research to the participants (see section 2.1 Procedure and questions asked). During the outlining stage of this value's attribution, the compatibility of different window characteristics to slightly alter the outdoor stimuli were considered following a scaled approach for manufacturing and customising the product in the study: the window. Recently Realyvásquez-Vargas et al. (2018) provided a model to measure macroergonomic compatibility of macroergonomic elements, factors, and work system. In their research, they underlined the fact that compatibility relies on the product ability to adapt its capabilities, limitations, and needs of another object to perform a specific function. Realyvásquez-Vargas et al. applied then this concept to a macroergonomic sphere, consisting of a perception based measurement of different macroergonomic practices. In our study, such an approach is transferred to users perceived compatibility of windows to adapt to human needs through a series of integrated design criteria such as light filters, glass colours, opaque glass treatment, indoor function, degree of privacy requirements, and outdoor connection. On another side, researchers such as Shankar et al. (2020), have discussed the importance of non-functional requirements (NFR) over the functional one, demonstrating that NFRs drive most of the design decision-making process and constrain how the product functionality is realised. In their study, functionality is approached by an environmental and stimuli point of view, and the product function is described by its action with or without external stimuli while it is being used. In our study, we confirm Shankar et al. theory and we also highlight NFRs as leading characteristics in users' discussion about the optimal window design to pursue the same functionality highly affected by the outdoor stimuli that Shankar et al. were discussing of; however, this study also highlights how the window functionality should adapt to the outdoor stimuli from the users' perspective. As in the previous subsection, a series of excerpts from participants' discussions follow to support the discussion on the second principle.

Table 4 Statements from the Focus Groups Discussion to support the Discussion on the first principle: FILTERING OUTDOOR STIMULI and CONTEXTUALISATION

	Statements from the Focus Groups Discussions
a	"..there are certain filters of which the colours are very tented, and you can't really feel what colour is it, but it will only compromise the amount of light getting inside, and this is one of the genius things of technology that works to compromise the light getting inside without compromising your emotions and affecting your positivity inside.";
b	"Cause even if you think that opaque part was a wall (Figure 3,o), you would have felt less connected if the window was only on the upper. So I think the size of the translucency is actually still connecting the outside with the inside. Cause you can feel the atmosphere. You are aware of what's happening outside.".
c	"I think that if the filter is not too extreme it can really make you understand the light from the outside is different, so it could be a good solution but it's necessary to make a study of what filter is best depending on each specific condition. However, once that you have established it's going to improve the environment, so I will use them.";
d	"Or maybe it could be, like for me changes if it's an office or if it's my house. Like an office, I don't care if they have red, blue, or whatever (glasses) because I'll go back home after. But if it's in my house, I think it will bother me to see like blue like the third picture (Figure 3,v) windows all around my house, and I would see blue everywhere that would bother me after a while.".
e	"We use this in our country, reflective glass, to maintain privacy. But it doesn't work after dark.";

f	"We need this especially in summer in UK (Figure 3,t-v). The sun raises till ten o'clock, I need my children to go to bed. (general laughing) Because they feel it's still early and they don't want to go to sleep. Their biological clock is type of that.";
g	"Yeah also, there's probably glass glow or something. And then that's typical top right (Figure 3,e) of a store or like you know where you want people seeing but not completely. So like maybe as at the hair dressers, nobody wants to be seen whilst their hair is being cut, but also they want some light to be able to work. So let's say it's for privacy, it's very commercial, it's not very necessarily pleasant, but probably necessary."
h	"I think it's applicable in clinics or in places where you need extreme privacy but still need some connection. It's better than a wall, that's sure. I mean imagine to have a wall and have this top window, it will make me feel really claustrophobic.".

According to the users' point of view, the filtering effect should be as natural as possible, as they want to achieve an *Outdoor Connection* while allowing an ideal indoor condition related to the function. Specifically for the *View* contribution and the *Amount of lighting,* this is supported by excerpts like the ones in Table 4.a,b. During the discussions, the participants highlighted the effectiveness of filtering the outdoor environmental conditions accordingly with the *Indoor Function* as the passages in Table 4.c,d attest.

Emphasised connection of *Filtering Outdoor Stimuli* categories with the *Indoor function* and with participants' *Life Experience Connection* occurs, also considering the consequent *Degree of privacy*. From the participants' point of view, the window has to be organic and adaptable to the human needs after those specific outside stimuli and indoor environment have been established. This demonstrates that the first approach of the user with window design is through research of Outdoor Connection and Affective Impact followed by a necessity of adaptation of the outside stimuli. Consequently, this principle turns to be also connecting with the *Affective Impact* macro category as you can see from excerpts in Table 4.e-h. The excerpts also demonstrate that there is a significant connection between the categories of *View, Listening, Comfort, Outdoor Connection* and *Glaze treatment*.

The second principle (*Filtering the information without changing the meaning*) introduces an additional value to window design when, in case of non-optimal outdoor conditions, the connection with the outdoor is not neglected but adapted. It is essential to stress further that the previous principle is related to the connection, while this establishes how this connection should be supported according to the users' perspective.

4.3 MANAGEABILITY and ARCHITECTONICAL INCLUSION: Controlling the window system behaviours within physical boundaries

From the previously explained principles, the participants' need to define which degree of connection with the outside they want to have according to several outdoor and indoor conditions is clear. This final principle determines users' need to control the window system to finalise the previous principles' application. In recent years, researchers within the Industrial Ergonomics field have systematically increased their focus on participatory ergonomics process based on the manageability of a product (Naweed et al., 2018; Pereira Pessôa and Jauregui Becker, 2020; Zhou et al., 2016). Naweed et al. (2018), for example, included in their study a console to control environmental conditions such as lighting. A virtual management practice was highlighted as fundamental to identifying the design limitations of a proposed case study and then optimising it through the user-based control system. Following the same approach, in the final stage of the focus group, the participants were presented with a number of before-after real case studies of indoor architectural design including windows. After having evaluated the 'before' examples, they were enabled to decide how to modify them through a series of design options offered by a virtual system built by the authors (see Section 2.1 at 4. Teamwork part). So through this immediate simulator, they were able to talk about the different options and then choose as a group the one they felt more comfortable with, according to how they wanted to manage the presented 'before' real case study. This method using participatory ergonomics and transdisciplinarity gave a unique perspective of the group underpinning simulated window design by substantive values and qualities which sometimes naturally lead to a collective function. On the investigation of maintainance evaluation method, also Zhou et al. presented valuable solutions. They specifically focused on describing the effects of ergonomics in product design, and formulated evaluation criteria based on ergonomic requirements as well as evaluated applications of such criteria on real design maintenance case. Finally, in the literature available, Pereira Pessôa and Jauregui Becker adopted an approach which is the most similar to ours. Within their findings, they presented the 'System lifecycle management' as one of the factors which directly impacts the design-engineering process of products. They also underline that Product Lifecycle Management Systems solutions should be dynamically adaptable and reflect the constantly changing working environment and organisation according to the human need. In our study, the same approach is highlighted from the focus groups discussions, where participants clearly expressed the need to be in charge of managing different window functional configurations to adapt the outdoor conditions to indoor comfort. A series of excerpts from participants' discussions now follow to support the discussion on the third principle.

Table 5 Statements from the Focus Groups Discussion to support the Discussion on the first principle: MANAGEABILITY and ARCHITECTONICAL INCLUSION

	Statements from the Focus Groups Discussions
a	*"But sometimes I open the windows to hear the street, I prefer that otherwise you are locked inside. So sometimes, just hearing the street, and if it is a pleasurable street, of course, it depends on the amount of noise in the outside. However, if it is set in a nice local street, I would rather open it. So you get some sense of the street.".*
b	*"For me, they are just different materials of the façade, and if you consider it as a window, you have to open it. Otherwise, I do not think it is a window."*
c	*"I think the bottom one (Figure 3,f) is the only one we choose so we can have some control over it. We can open it for some ventilation."*

Most of the time users associate the *Manageability* macro-category with the *Architectural Inclusion* one (through *Frame shape, Design, Inclusion or extrusion off the wall, and Frame thickness* categories connections). However, they also have associated *Manageability* and *Architectural Inclusion* macro-categories with Affective Impact, Contextualisation, and *Filtering Outdoor Stimuli* (through categories connections with *Outdoor Connection, Anxiety, Listening, Glaze treatment,* and *Panel division)*. This means that the third principle is applied within the previous two principles decision-making process about the Value Attribution of ergonomic window design from the users' perspective.

The importance of the window control is supported by excerpts like the one in Table 5.a. Alternatively, statements like Table 5.b show the crucial role of window settings' manageability to maximise or minimise the outdoor connection.

On the other side, high interest was expressed in visualising the window system functionality as part of a higher architectonical composition where this is placed. In particular, they commonly relate categories like the *Ventilation* with *Frame shape, Design, Frame thickness and Inclusion or Extrusion off the wall.* According to the participants, the connection between these categories identifies the window as a functional part of the building. It also defines the opening of its external boundaries towards the outdoor context (see Table 5.c). This third principle draws the final relationships between the macro-categories and the Value Attribution of Ergonomic Window Design from the users' perspective.

4.4 Implications of the three Principles for research and practice

These three principles can establish essential guidelines for both researchers in Architectural or Building Engineering field as well as designers and professionals who work on window design optimisation process. For the researcher in these fields, it is fundamental to consider the importance for users' control over the window system due to a variety of outdoor and indoor contexts and with different degree of connection between them. In this study, a correlation between the expression of increasing people's comfort and their awareness of being in charge of actuating window-related mechanisms (such as natural ventilation, natural lighting, and so forth) has been demonstrated. Further study could consider, for example, specific cultural or geographical scenarios or conditions, and develop window design studies focusing on specific macro-categories. For the designer or professional in window's innovation and production, these principles could be an efficient tool to improve the appeal of a product in the Engineering or Architectural market. This study demonstrates that people feel more comfortable when they are in control of the window's functions, specifically if the technologies allow them to use more natural sources and limit the artificial ones saving energy and money and increasing their well-being. Nowadays, product sustainability is one of the most competitive fields in building engineering and architectural innovation. (Santolaya et al., 2019) The principles derived from this study could be used to improve the window design and production not just from an ergonomics point of view but also from an energy efficiency perspective towards a more sustainable building system.

5. Conclusions

A new approach for window design methodology was investigated involving social science techniques. The main aim was to understand the principles that define the value attribution of ergonomic window design from the users' perspective. Focus group and Grounded Theory methods have been used to study and code participants' discussions by the degree of interest in the selected visual stimuli and the employment of specific window design technologies to modify the window's settings and adapt outdoor inputs to indoor comfort.

Results framework have been established through the relevance of the relationship between the 25 categories, grouped in 5 main macro-categories. The macro-categories' relationships were then used to describe the principles that drive the value attribution of ergonomic window design from the users' perspective. The three principles defined were: 1) Importance of the Outdoor Connection to feel oriented, 2) Filtering the information without changing the meaning, and 3) Controlling the window system behaviours within physical boundaries.

It was highlighted that participants perceive the window as an essential mediating instrument between the indoor and the outdoor of a building. Through this feature, they feel connected to the outdoor environment. Despite the non-optimal conditions, they feel oriented and perceive an improvement in the indoor's affective impact. In the second place, participants expressed a relevant interest in the glaze treatments or window technology to be able to mediate outdoor physical inputs (such as thermal, lighting and acoustic). According to them, the application of such technology must follow specific principles to keep the perception of the outdoor as authentic as possible. Finally, the participants wanted to be involved actively in window management, according to their specific needs based on the relative contextualisation.

This research aims to draw a new methodology for window design, which considers users' preferred aspects and combines them with a specific window's technologies. As results, the methodology could be used by Engineering and Architecture researchers to investigate the optimal building feature design ergonomically according to the users' perspective. Moreover, the final categories could be applied to study real scenarios and help other researchers better investigate some of the categories or support designers or window's companies to develop a more refined proposal for a specific window's application. Finally, the three main principles, related to window design requirements from the users' perspective outlined in this study, could be used as a guideline for optimised ergonomic window design for both building engineering and architectural research or professional application. Through the use of these principles, there could be a significant improvement in terms of window innovations. It could be possible, for example, to draw windows design prototype depending individually from the macro-categories and categories (as highlighted from the analysis stage) defining specific optimal window requirements. The window design would become then not only the mediator between the outside inputs and the indoor comfort, but it could even modulate the first one to optimise the second.

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