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Eye tracking and architectural design : can reference photos reduce the architect-user gap ?

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Eye tracking and architectural design

Can reference photos reduce the architect-user gap?

Thesis with the aim of achieving a Master degree, ENSA Nantes

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Directed by Laurent Lescop

ECOLE NATIONALE SUPERIEURE D'ARCHITECTURE DE NANTES
DOCUMENT SOUMIS AU DROIT D'AUTEUR

Nantes, France

14 January 2022

To Geddo.

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Contents

Acknowledgements	III
Abstract	IV
Preface	2
Introduction	6
1 Which place for the user in the design process?	10
1.1 Designing for/with people	10
1.2 Symbolic violence	12
1.3 Towards symbolic justice	14
1.4 Conclusion	23
2 Imagery in the architectural practice	26
2.1 Thinking by analogy	27
2.2 Photography, to speak/listen	29
2.3 Reference photos	32
2.4 Conclusion	33
3 Revealing signification in reference photos through eye tracking	34
3.1 Attention-based data	35
3.2 Signification of gaze points	36
3.3 Graph-based data	38
3.4 Recommender systems	39
3.5 A framework for using eye-tracking in architecture	40
Conclusion	47
References	49
Figures	53

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Abstract

Eye tracking is a research area in Psychology that has demonstrated impressive ability to understand user behavior. Its application in participatory design has developed recently, but its use is still limited in architectural firms. This research provides a survey of eye tracking technology, and contributes to its implementation for massive participation in architectural design involving the users their subjective representation of the space. Methods for working with big number of participants are introduced and data interpretation methods are shown to analyze the users' input.

Keywords: participatory design ; affordances ; eye tracking ; recommender systems

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Preface

After some months of studying in an architecture school, a student lives a transition in the way of perceiving architecture from a mere inhabitant to the creator of a space. This comes with a good foundation in the architectural discipline and its history, putting the student in a continuum with Palladio's heritage. It also comes with leaving some ideas behind, abandoning some expectations that are not relevant to what the architect does. Such is my case, as I'm writing this Master thesis I realize that a lot of my prior ideas about the architect's responsibility have changed. Except one. That the architect is responsible for how people feel and behave in the space created. For me, this is one of the most fundamental function of a space. Our well-being is directly influenced by our environment.

The space that the architect creates has many dimensions. Of course, the three known geometric dimensions, the classic Euclidean geometry. But Edward T. Hall informs us, already in the 1960s¹, that there is also a hidden dimension. We do not all see the same thing. And what we perceive, the stimuli to which we are exposed, makes its way in our brain and then in our actions. Winston Churchill once said: "*We shape our buildings; thereafter they shape us.*".

These ideas have haunted my mind since the first time I started design. It wasn't an architectural design though, my first experience was with graphic design. This start taught me a lot about the influence of creative content. Since the scale is pretty different and definitely smaller, a lot of my attention was oriented to the user behavior. How to convey certain emotions? How to make this product

1. Hall, *The Hidden Dimension*.

more user-friendly?..etc. In architecture school, I shifted from small to bigger scale. Then, making a user-oriented design was not possible. Our design project has certainly a lot of criteria to satisfy, but the user may not be on top of them. This is not surprising, since these school projects are not dedicated to be realized in real life. Students are free to take a distance with regard to reality, as do the teachers as well.

I was lucky to have classes in my school that were worried about the social life in buildings. Accompanied by researchers or practitioners in social sciences, we had workshops where we studied how social housing units are used by the inhabitants. This critical analysis of the architectural space was enlightening for me. This observational approach towards people's behavior in a space underlines the gap between the architect and the inhabitant. It was clear for me that this is a domain where architects' effort should definitely be engaged. These efforts are mainly intellectual, since the architect is a creative author above all. But not oriented to the design process in the first place, rather more fundamental than that. It's more about intellectual efforts to accept the idea that architecture is a user-oriented creation. The chance that I had to work with a sociological approach was not true years ago in architectural schools. In 1966 when Henri Raymond, social scientist, was invited in the design workshop of Louis Arretche, a known French architect, he has felt that his sociological input was considered with some sort of "mediocrity"². Raymond thought that the sociological arguments were instrumentalized by architects to find reasons for their choices or to convince the user of their reasoning. It's unfortunate since the goal of such arguments is to create a real sociology of the living space. In the words of Jean-Pierre Frey, architect and social scientist: "*It is*

2. Raymond and Frey, *L'architecture, les aventures spatiales de la raison*, 17.

a question of operating a painful withdrawal from the aptitude acquired in the design workshops to impose at all costs their views to aestheticize the world."³ He underlines that the core issue starts in the architectural school itself, and the way of teaching design.

It's easier to point the problem than to solve it. Bringing all the users, with all their differences, around the same table is a quite hard mission. How can we create a right environment for everyone? The architectural project, contrary to other forms of creative production like the example of graphic design mentioned above, vary greatly in scale. It can be a small piece of furniture or an urban renovation of a whole neighborhood. How can we take into consideration all the potential users with all their subjective differences?

Having studied abroad in two different schools, one time in Nantes, France, the other in Stuttgart, Germany, I have been a foreign student twice. I have realized that what makes an individual a foreigner is, above all, about what Barthes called the *cultural code*. Take for example the social housing and the "grands ensembles". In my country Egypt, there's no direct negative connotation of such typology like in other European countries. Quite the contrary, the new capital that is being constructed, even finished as I'm writing now, is full of big residential buildings. It became part of the social life, and people embraced habits that correspond with these settings. The cultural code then is very different from each individual's point of view. The same object doesn't have the same connotation in our eyes.

3. Raymond and Frey, 14.

I started this research project without knowing where I would end. I just had one objective in mind. My goal was to find some door to access the subjectivity of users. It was a far and vast goal, but at least with this paper I try to bring it closer to reality. The questions I asked to proceed in my research brought me to very different fields of research. To understand the human being in the surrounding space, I had to go through texts in sociology, psychology, neuroscience, ecology..and many others. I surfed from one humanistic school, to another. Sometimes I found simultaneous researches that address comparable issues, but with no direct relation between the authors. Like the example of social psychology in France and environmental psychology in the United States. Or even the research lead by Christopher Alexander, and the empirical research in ecology that both dealt with the structural language of the built environment but with little connection between both. I had also to have a look on the inevitable field of artificial intelligence. The progress that is done with recommender systems is implemented in tools that we use on a daily basis. It recommends very personalized content as if it has some comprehension of our own subjectivity. Research in eye tracking has made a lot of progress in this field as well, trying to understand the human behavior through the cognitive activity of the brain.

I tried then to get together many disciplines, that sometimes are not directly related. And my intention was to make a study that is well-founded in academic disciplines, yet at the same time has a direct operational application in architecture offices. I hope that these efforts can contribute to integrate the user in the design process, and to be useful to others who share the same questions.

Saif Aletriby

Introduction

Subject and object of research

In the 1960s, there was a wide awareness that the built environment had a significant influence on the behavior of people. Pioneered by critics like the journalist Jane Jacobs⁴, it was a reaction to the failure of the post-war urban and architectural development to create sustainable communities. In the example of Pruitt-Igoe, the fast reconstruction period had come with fast social instabilities in new urban spaces and after 20 years such troubles grew higher and higher to the point that the operation was completely demolished. Designers and planners started then to reflect on solutions to prevent this undesired behavior in future environments. It was then followed by much academic research that brace different fields in order to solve the complex problem of space and human behavior. Soon enough, the idea that the user should be part of the design process became obvious. Many methods were used and the participation of the users differed in scale and nature from project to another.

Postulate / Questions

Despite many approaches to participatory design, the actual application in the design firms is still limited. This can be explained by many reasons. One of them is the fact that this approach demand long term engagement from architects to join workshops, lead surveys, create and recreate drafts..etc. This is very time-consuming and then has considerable economical price. Besides, the classical methods of survey are limited by the number of participants. How

4. Jacobs, *The Death and Life of Great American Cities*.

can the architect manage the complexity of integrating the ideas and opinions of all users of a space? The action research in participatory design that is maintained since the 1960s is enlightening to architects, but in many cases it involves new tools and methods that are relatively new to architects and take some time to implement. There is still some distance between the architectural profession as it is practiced today, and the participatory design methods that are growing considerably nowadays.

Another challenge to participatory design is the considerable difference in individual perception and representation of space. People are different, and hence see the space differently. Each user has a different social and cultural capitals inherited from different social structures. How can the architects with their own cultural capital manage to understand precisely what the user has to say? What if the users' needs are even hard to explain in words, and are rather implicit and non-verbal? How to decode the signified/signifier system of every participant? Is there a way to review the conventional design process as it is practiced in architectural firms today, and integrate sociological insight into tools already used by architects? What tools are possible for massive participation in participatory design?

Posture

This research tries to find a common ground between the space *producer* and *user*, if we use the terms of Henri Lefebvre ⁵, to achieve a successful integration of the user in the design process. It's about finding tools that are already been used by architects in the design process, and that can be of relevant value to integrate the user in

5. Lefebvre, *La production de l'espace*.

the space production. It gets inspiration from participatory design approaches to bring a critical view on tools used by designers. Nevertheless, it doesn't take these participatory approaches as a subject of research.

The text takes an ecological approach of environment as the configuration of prominent stimuli, and then studies how individuals perceive the space, everyone with their own representation, and the eventual patterns in such behavior.

The references used to achieve this text are of very different disciplines and schools. Since the leading question of this research is by nature very interdisciplinary, the literature reflects the same nature. We studied linguistic and semiotic foundations for individual representation, and crossed them with social psychology as much as environmental psychology in France and in the United States respectively. Every reference brought its own view on the questions. In some cases they were converging, but with different terminologies, and in other instances they were fundamentally different. Like the difference in the descriptive and prescriptive approaches between the schools in social sciences in France and the United States.

We studied architects who shared this *ecological*⁶ view of space such as Christopher Alexander and his inevitable principle of *patterns*⁷. His writings can be seen as a structuralist approach to architecture, despite the lack of connections between his research and the psychological or sociological research in environmental studies.

6. In the sense that it studies the human being in their environmental settings.

7. Alexander, Ishikawa, and Silverstein, *A Pattern Language*.

The limits of research

At the end of this study, we explain how this theoretical foundation can be applied in the operational tools of the design process. We then study eye tracking technologies available and their potential application in architecture. It's then important to specify that it's only a question of eye movement data, without any facial gesture analysis, and then no prediction for participants' emotions. Since the main objective of this research is to implement it in massive user participation, we then focused the study on virtual surveys. In-person surveys are frequently used in other eye tracking experiments and they offer a lot of precision in the subjective analysis of users. Yet they're limited by the number of participants. In our study, the main goal is to achieve the higher participation of users possible with tools accessible to everyone. The use of qualitative survey is then re-directed on other possible semantic analysis.

Methodology

First this study starts by giving the theoretical foundation in social sciences for representation, and perception. Then, the subject of imagery and how it's used in architectural practice is studied, which leads to the specific object of architectural reference photos. At the end, this object is studied in relation to eye tracking and how this technology can bring relevant insight on subjective perception of reference photos whether they can be used by architects to reveal patterns in users' behavior through eye tracking.

1 Which place for the user in the design process?

1.1 Designing for/with people

As participatory design aims to integrate the user in the design process, it's faced by many challenges in the architectural field. It's not quite easy for architects to share the privilege of design and decision-making with someone else. As Mario Carpo said it clearly in one of his conferences: "*architects are permanently at odds with the rest of the world, or a permanent pain in the neck of the society.*" The space is orchestrated by the architect, and the users should fit in somehow. This is one of the main difficulties in participatory design. When Thierry Paquot was addressing the subject of co-construction in the work of Hassan Fathy, he said that the collaboration of the users was limited to the construction phase.⁸ Fathy was precursor in cooperative construction with his experience in the village of Gourna⁹. Despite that, he confirmed in the first pages of his book that he wanted to "to build a village where the peasants would follow the way of life that I would like them to."

In the same way, user participation is not synonym of user implication in the design process. Paquot makes a difference in designing *for* and *with* the people. Since the design process is a long one that can last months or years, the user may be integrated in different phases of the process. Yet integrating the user in the conception

8. Paquot, "Hassan Fathy, construire avec ou pour le peuple?"

9. Fathī, *Architecture for the Poor*.

Which place for the user in the design process?

phase is the most difficult and the most challenging. The *space producer* and the space user are very different culturally and socially, which makes it more difficult for the architect to listen to the user, and to understand their *cultural codes*.

This difference in cultural codes is obvious between architects and the general public. Frank Lloyd Wright when asked about people who do not like his buildings, said in an interview: "I don't think they matter as far as I am concerned.". Architects have been imprisoned in an arrogant shell for a long time, with their own vision of what is right and what is atypical. It makes it easier for them to take decisions. Like in old medicine, where the medical studies to test the effect of certain drugs on patients were made mostly on the male individuals, since it treats men as the default and women as atypical¹⁰ This has caused a lot of bias when these drugs were used by women. Every individual is different, everybody reacts differently to its medicine and then all individuals should be included equally in research. If we consider the problem expressed by Perez in the medical field in architecture and urban planning, we find by analogy that design is far away from considering all the differences that exist between individuals, not only regarding gender. The paradox is that Le Corbusier himself considered architecture as a remedy, when he said: " *On the day when contemporary society, at present so sick, has become properly aware that only architecture and city planning can provide the exact prescription for its ills, then the day will have come*

10. Criado-Perez, *Invisible Women*.

Which place for the user in the design process?

for the great machine to be put in motion"¹¹. Whereas when he designed "Unité d'habitation" in Marseille, a very precise vision of how a modern European family should live was imposed. If he thinks of architecture as a remedy, then it concerns very specific people.

It's quite obvious that deep differences between the designer and the user result in considerable gap between the end product and the user. When the designer doesn't share the same codes as the user, then how can they perceive the built environment the same way? They both have a brain, but they don't perceive and think the same way.¹² Hence, it's not when the designer considers the impact of their creation on themselves first that the design is more human. Gropius said that "*Architecture should satisfy the human soul*"¹³, but don't we have different souls? Like medicine, architecture should not be tried on one individual before being applied on the public, rather all categories of users should be taken into consideration before achieving a design.

1.2 Symbolic violence

The term *symbolic violence* was first used in 1970 by Pierre Bourdieu and Jean-Claude Passeron.¹⁴ Both studied dominant significations in the education, and the relationship of power between the dominant and the dominated. They came up with a theory where social order is imposed through significations of the dominant. In educa-

11. Le Corbusier, *The Radiant City: Elements of a Doctrine of Urbanism to Be Used as the Basis of Our Machine-Age Civilization*, 143.

12. Mallgrave, *The Architect's Brain*.

13. Gropius, *Scope of Total Architecture*.

14. Bourdieu and Passeron, *La reproduction*.

Which place for the user in the design process?

tion this is a serious problem since, as they explain, it is an arbitrary signification of an arbitrary power. Why such significations should be imposed on knowledge seekers as the norm whereas they do not relate directly to the act of seeking knowledge?

One may ask the same question in architectural design as well, since design making is, in many cases, about arbitrary decisions. From its beginning, the semiological school of Saussure acts with all objects as significant and carrying meaning. Hence, objects inside an architectural space should be considered as such symbolic elements. And the act of choosing an object with certain attributes is a symbolic action, that can be either *violent* or not. The architect's decision has considerable consequence in the everyday life of space users, and in this sense can privilege a social or a cultural order.

In fact, the architect is not innocent. They have their own *cultural capital*, and it has a direct resonance on their reflection and production. Bourdieu and Passeron explain that the distribution of cultural capital by the educational action is a way of reproducing certain *social structures*. We can apply the same theory on the design action, since it shares the same immersive aspect. It's hard for the design or the designer to be completely neutral. But it's still a real challenge for the architect to ignore their own cultural codes, and try to embrace different codes.

Which place for the user in the design process?

1.3 Towards symbolic justice

1.3.1 Structuralist architecture

The revolutionary ideas of structuralism, brought by Saussure and revived by Levi-Strauss, influenced some architects. They were inspired by the idea that human beings belong to social structures, and these different social structures are inter-related. This concept opened the door for architects to go in other cultures to find architectural knowledge and experience. This came up with a new generation of architects whose ideas, in opposition to the CIAM generation, are not euro-centered. Team X, with distinct figures like Aldo Van Eyck, is very representative of this new movement in architecture in the 1960s and 70s. The idea to look for inspiration in local traditions and even in foreign, maybe “under-developed,” cultures was no more a taboo. There was less fascination for an ever-growing technology, and a research for humanistic architecture.

The understanding of cultural meaning and signification can be read in Van Eyck’s words, when he said: *“The time has come to invent new significant identifying devices that perpetuate in a new way the essential human experiences the old ones provided for so well. At the same time those new ones must provide for equally essential experiences the older ones no longer provide for, or never did.”*¹⁵. Van Eyck considered the architectural elements as significant, and carrying meaning. Instead of searching for new technological elements, he suggests to see what is significant in existing environments and to try to reproduce it.

15. Van Eyck, *Steps towards a Configurative Discipline*.

Which place for the user in the design process?

Rationalist preoccupations of modernism were criticized for the sake of a deeper understanding of how architecture influences human beings in an individual and collective manner. Van Eyck suggested that the architecture should consider individuals and the society as a whole. It cannot satisfy one without the other. For him, in order for the architecture to be significant, it should “*coincide to some extent at least with the illusive configuration of the individual and the collective.*”¹⁶

The meeting of Team X in Otterlo 1959 was very important to give a voice for the cultural signification of space in the architectural community. Since their first meeting, the architects took reference in native and primary cultures. They also gave the priority to the inhabitant, and how to create stable communities.

1.3.2 Open building

To solve the issue of signification in architecture on an operational level, many solutions were proposed. Some tend to liberate the architecture from any symbolic signification, and others aim to understand the complex language of space. John Habraken was one of the first category, who invented the concept of *open building* in 1961¹⁷. It's based on the recognition of two domains in which the building exist; the community and the individual inhabitant. When the building is dedicated to a social structure, or a community, it may be rigid and may exclude some inhabitants. When it's left

16. Van Eyck.

17. Habraken, *Supports*.

Which place for the user in the design process?

entirely to the inhabitants' will, then it may turn into chaos. His method was to distinguish the support from the infill; the general built structure where all community members exist, and what users can individually decide for their own private living space.

Using this framework, Habraken managed to create a place for the inhabitant in the design process and contributes to the participation of users in the design process. In front of such a complex situation where all users are different, Habraken chooses abstraction and simplification to enable more flexibility. Another example of such method is the Ökohaus that was built in Berlin by Frei Otto. The German architect created the infra structure for the whole residential building, and let inhabitants draw their own houses with his support.

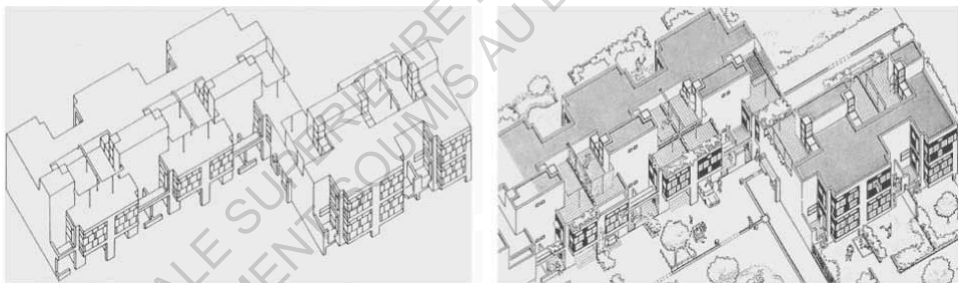


Fig. 1: Diagoon Experimental Housing in Delft by Herman Hertzberger 1971

1.3.3 Pattern language

Open buildings may solve the issue of user participation, but intentionally draw away from any exposed cultural code in the architectural space. Nevertheless, Habraken has later taken a new approach to space. In “The structure of the ordinary”¹⁸, he suggested that architects should undertake the study of ordinary places as a fertile

18. Habraken and Teicher, *The Structure of the Ordinary*.

Which place for the user in the design process?

common ground where place-making is rooted. He supports the idea that precedent environments hold a certain signification in people's mind and that's how these settings offer coherence and well-being.

This is precisely what Christopher Alexander, also an architect, has implemented in his book "A pattern language" already in 1977. Alexander searched with the Center for Environmental Structure of Berkeley for recurrent patterns in existing settings where the environment offered a livable space for its occupants. He believed that there is some objective truth behind spaces that are full of life¹⁹. He then tried to assemble from his own experience the patterns that exist in living environments. Relevant objects are arranged in micro settings. The composition of these micro settings together result in a macro setting that he called a *pattern language*, meaning that the building is put together in a coherent manner.

This notion of pattern is used a lot in analysis tools nowadays. Be it in social science, or in computing, the study of patterns gives important information about a system. It makes it easier to decode a complex dataset through mechanisms like clustering.

1.3.4 Behavior settings

The patterns chosen by Alexander exist in settings that are full of life, where people feel good and maintain a good activity in small and big communities. The same ecological approach was also followed by other researchers. In fact, ecological psychology is an established field of psychology that studies the individual within a social and a physical setting. Roger Barker was one of its pioneers.

19. "Christopher Alexander, Keynote Speech to the 1996 OOPSLA Convention."

Which place for the user in the design process?

He was the first to use the term behavior *settings*²⁰. By this term, he means a duality between human behavior and the *setting*, or the *milieu*, where the action is being done. Contrary to cognitive psychology, Barker tries to explain the human behavior through repetitive patterns in behavior within a population and in relation to a spatial setting.

For him, there is causal relationship between both. In a small Midwestern town of the United States, he and his colleagues studied the daily activity of the children.²¹ They found that *patterns* of behavior within children groups emerge in each physical environment. The behavior of an individual child had greater variability across different locations than the behavior of different children in the same location. His idea that these patterns of behaviour are sustained by the collective behaviour of the social systems, joins the mechanisms of reproduction described by Bourdieu.

Further understanding of behavior in given settings can be explained by the concept of *affordances*. James Gibson coined the term in 1979 to describe what the environment provides to individuals as a potential to interaction. It also describes the interrelation between the environment and its users. The functional properties of the environment exist as a result of the individual's perception. The interaction can only exist when the environment and the user relate to one another. With semiological understanding of this concept, affordances are a function of how each individual interpret the surroundings based on a signifier-signified system. The ecological

20. Barker, *Ecological Psychology*.

21. Barker, Wright, and Barker, *One Boy's Day*.

Which place for the user in the design process?

approach studies mainly the recurrent patterns in different social structures, as Christopher Alexander did. An understanding of the user's behavior may be possible through cultural codes, and the signification of such settings to individuals.

1.3.5 Subjective patterns

The patterns that Alexander and Barker have detected are mainly sociocultural. It was not question of how precisely every individual perceive the environment. It's a structuralist understanding of patterns, where they're not isolated from their *milieu* or their structural system.

One of the main goals behind this research was to find an approach to understand the subjective representation of different participants in a design process. In other words, if Alexander studies the objective patterns in built environments, then we wanted to study the subjective patterns.

The intention here is not to break with this tradition of patterns detection. Rather, we wanted to cross it with the semiological tradition that exist in sociology and to put some nuances in the general guidelines of "a pattern language". The goal is to understand the subjective representation that motivates the user's behavior. Despite this, it's not question to study the cognitive activity of each user. The question is then how to decode the user's signification of the setting that motivates their behavior?

The answer to this paradox can be found in semantics and its application in recommender systems nowadays. Recommender systems are used in many applications in our daily life; like Youtube, Netflix or Pinterest. Its main function is to predict how a user may like a certain content, and then recommends it.

Which place for the user in the design process?

In ecological terms, the *setting* would be the platform, for example Pinterest, and the behavior would be to “pin” a certain content. The predictability that Barker talked about would be the capacity to predict if a user would pin a certain content on the platform.

The difference with the academic framework of Barker is that recommender systems are capable to relate efficiently users and content, and then detect new patterns of behavior based on similar behavior. This can be of great use for ecological studies since the predictability, which is the valid argument of behavior setting theory, is raised substantially.

In a recommender system, users with similar behavior are related. In Pinterest, if two users pin the same content, then there’s more probable that they like the same things. Based on that pattern, the neural networks recommend new contents, and tries to predict new behavior between users and contents. It’s not surprising that Pinterest considers itself “at its core, a data and AI company,” according to Vanja Josifovski, its chief technology officer until 2018.

Another way Pinterest makes recommendations relevant is through semantic labelling. A neural network called PinSage, places each image according to theme within a giant “graph” of other images. The graph is composed of three billion nodes with 18 billion lines that connect them. This way, Pinterest can recommend thematically similar images for users. The same semantic approach is used by Netflix, but with a broader implementation. It lets users describe every content (a movie) with their own words, creating something close to subjective classification.

Which place for the user in the design process?

With a structuralist view, the language is a social structure and then should reveal some patterns. The use of such technology can be useful to take one step closer to understand the cultural code that motivates user's behavior. With words and semantic input, it becomes easier to classify behavior and then find patterns.

1.3.6 The photograph, a non-coded medium?

In fact, the example of Pinterest is quite interesting for the architectural practice nowadays. Both architects and clients use the online platform to get inspiration and to dive deeper into their preferences. With its enormous visual database, and a solid recommendation system based on dense semantic tags, Pinterest suggests significant images to all its users and for all reasons. It creates clusters of similar photographs based on user input. The platform is accessible for everyone. And its main object, which is the image, is accessible to everyone regardless of the public.

The image itself was for a long time a subject of interest of Roland Barthes. He considered the press photograph as the perfect *analogon* of reality.²² An image transmits objects from reality, with certainly some reduction, but without any transformation. Furthermore, it's a message without any *code*; every person can interpret it through their own *cultural code*. It is the mechanic *analogue of reality*. It doesn't contain a second message. Contrary to text that implies a *connotation* from the reader or the listener.

22. Barthes, "Le message photographique," 128.

Which place for the user in the design process?

“[...]this same photograph is not only perceived, received, it is read, attached more or less consciously by the public which consumes it, to a traditional reserve of signs; however, any sign supposes a code, and **it is this code** (of connotation) **that we should try to establish.**”²³

In the upper citation, Barthes describes a connection between a photograph on one side and social structure with its cultural codes on the other side. By understanding the different implicit codes that a photograph triggers to different users, we can understand something about their subjectivity. We find that this quote reflects pretty much what we want to achieve at the end of this research, to establish the subjective code of users in relation to photographs and to use this to detect patterns between different participants.

But same as with Barker’s approach, this understanding give a guess about what happens in the mind of individuals without certainly taking it as a subject of study. As in recommender systems, where the machine learning manage to understand something about users only with the analysis of their behavior, and without looking at their cognitive activity. But these ideas are even accepted by the cognitive approach to perception as Mallgrave explains his principle of *embodiment*: “The brain does not merely sense the world; it actively confronts it with its own representational models.”²⁴

In fact, the claim that perception is produced by individuals, and that objects are only meaningful when interpreted by the human is close to be an idealist idea. This suggests that every individual has a personal *repertoire*, or a memory. This repertoire is used to examine the *percept* and compares it to a system of similar objects that were experienced by the individual.²⁵ In opposition to this approach

23. Barthes, 130.

24. Mallgrave, *The Architect’s Brain*, 2011.

25. Edeline et al., *Traité Du Signe Visuel*, 89.

Which place for the user in the design process?

where there's no absolute truth, positivism suggests that the meaning is embedded in each object and it's not a product of the human perception. It's interesting to see these two approaches as two sides of the same coin. The objective embedded information that an object may contain, makes it easier for a recommender system to work on subjective patterns.

But how can a human judge a place from its image? Gibson has studied this question in the context of child education.²⁶ What he noticed is that the individual do not see forms in an image, they only detect *invariants*. The invariant is the object itself, as it may be known in reality, without any variable attribute. The individual is capable of recalling a real setting or elements that they have experienced in reality. He believed that situations could be simulated.²⁷ Based on this point of view, we consider the photo as an object that can reveal the participants' representation of reality.

1.4 Conclusion

In a participatory design process where architects work hand in hand with users, the project needs to be considered in all of its dimensions. The hidden dimension of cultural codes should equally be addressed. The built environment contains a symbolic signification that is different from one user to another. The architect has also their own representation that is influenced by their cultural codes. To avoid unequal spaces, architects should consider how their buildings is perceived by all individuals involved. It's a difficult mission, since perception is a very subjective matter. Rather, the ecological approach offers a possibility for considering the user behav-

26. Gibson, *The Ecological Approach to Visual Perception*.

27. Gibson, 261.

Which place for the user in the design process?

ior in the architectural setting by studying patterns in behavior. To understand the motivation behind such behavior, an understanding of cultural codes is essential. To simulate real built environments, researchers argued that photographs can be considered as the analogon of reality and then the behavior in front of such images can reveal something about their personal representation. By analogy, the image of a space contains the significant analogon of objects in the space.

As shown in the chapter, new technologies make it easier to understand these patterns. The example of platforms like Pinterest is a good example for the potential of imagery. It can detect patterns in users' behavior towards photos. These technologies can be implemented in the architectural practice if we study more the place of imagery in conception, and how it is used by architects and the possibility for it to be used as medium of communication between architects and users.

Which place for the user in the design process?

“An old house, a shady porch, roof tiles, an old Arabic decoration, a man sitting against the wall, a deserted street, a Mediterranean tree: this old photograph (1854) touches me: it is simply there that I want to live.”²⁸



Fig. 2: Wine tower in Alhambra, Granada. Photo by: Charles Clifford in 1854

28. Barthes, *La chambre claire*, 16.

2 Imagery in the architectural practice

Some obstacles in implementing participatory approach in architectural design, are about the considerable change in method that architects should apply in the design process. Architects have traditional frameworks, where they deal with complex variants. Changing their method has a direct organizational and economic impact. As a result, few designers would engage in a participatory approach. Despite the visible gap between the architect and the user, there's still some common ground that is not fully explored. As argued in the previous chapter, the photograph proves itself as a powerful communication method between architects and participants. It enables the participants to visualize a virtual setting and evaluate it based on their needs, as we saw with Roland Barthes and his Alhambra photograph.

In this chapter, imagery is studied in relation to the architectural practice. How important is the visual representation in the design process? How architects use the image to communicate? Which type of images can be useful for communication between architects and users?

2.1 Thinking by analogy

The image is above all an analogical content. It's not reality, but we see it real through metaphor and similarity. The human mind is capable of making abstraction and seeing invariants. The structure-mapping theory of Dedre Gentner suggests that our knowledge, and hence our memory, is organized in a structural manner where ideas relate to each other by analogy. In fact, architects also use analogy in design thinking. As Alexander argues, the architectural design is about creating forms that fit well into a given context.²⁹ A context can be anything that the designer should take into consideration in the design process. Certainly not all contexts are similar, and so is the architectural form. Despite that, the designer manages to relate with other concepts and models that were produced by other designers elsewhere. This comes with a deep understanding of structural interconnections between contexts and forms. In this way, designers avoid literal similarity in apparent object attributes and search for more significant points of convergence.

In fact, this practice even exists in architectural schools. The architectural education uses some corpus of references where acclaimed figures, movements and buildings are studied and then implemented in the design process.³⁰ It's a transmission of knowledge, even if it's not linear and hard to structure into one corpus. Architects share some references, and without it the communication between them would be hard, and the architectural practice even harder to transmit.

29. Alexander, *Notes on the Synthesis of Form*.

30. Texier, "La référence dans l'apport du projet architectural et urbain. L'apport de l'ENSAPBX dans la construction d'un référentiel."

Habraken even put analogy in the center of design, when he argued that implicit common understanding in *ordinary* buildings makes it possible for architects to innovate while maintaining coherence.³¹ As in modernism, the eager will to continuously innovate may result in a gap between what the architect creates, and what the user knows. By nature, human minds relate more to familiar objects.³² Familiarity is a result of previous experiences, where individuals have attributed a certain signification to an object in a certain setting. We're more attracted to objects we know, and hence are more likely to interact with them. It's an unconscious action from our brain. *"Analogies often spring to mind suddenly and unexpectedly. The detection of analogies likely transcends an unconscious stage before entering consciousness."*³³

These views are shared by the structuralist Dutch architect Herman Hertzberger. Hertzberger suggested that there should be a continuum between old and new. He said: *"[..] When we do away with what has gone before us, and pay no attention to what more stable groups of people next door to us, or elsewhere, still possess, and thus make no use of the accumulation of images at our disposal, we nip the possibility of renewal in the bud."*

With ideas like the *Musée Imaginaire*³⁴, he expressed the meaning of analogy in the architectural practice. It's like a huge repository of images, from which the architect takes reference and gets inspiration. What Habraken called sharing an implicit common understanding, is also shared by Hertzberger who suggests that by doing so, architectural elements gain new signification that are well established in the social structure. Furthermore, references are re-evalu-

31. Habraken and Teicher, *The Structure of the Ordinary*.

32. Holyoak and Thagard, *Mental Leaps*.

33. Reber et al., "Detecting Analogies Unconsciously."

ated by architects and are given new significations. He said: *“We cannot make anything new, but only re-evaluate already existing images, in order to make them more suitable for our circumstances. What we need to draw on is the great “Musée Imaginaire” of images, wherein the process of change of signification is displayed as an effort of human imagination, always finding a way to break through the established order, so as to find a more appropriate solution for his situation. ”*

In this way, designers create spaces that maintain some continuity with previous architectural heritage and with social habits as well. Hertzberger endorses an archeological view of the architectural knowledge, that is organized in layers and to which architects contribute by adding layers on top of it. He adds: *“The various significations of everything that has taken place, and is still taking place now, are like geological layers lying one on top of another; and they form for us in their entirety, the undercoat on which a new layer may be placed; a new signification, which will slightly alter the whole thing. This transformation process, whereby the outmoded significations fade into the background, and new ones are added, must be ever present in our working methods. Only by such a dialectical process, will there be a continual thread between past and future, and the maintenance of historical continuity.”*

2.2 Photography, to speak/listen

The place of architectural photography, which is our main subject of interest here, is of great relevance to the architectural practice. The use of photography by architects is as old as the history of photography itself. Iconic photos of renowned buildings are stuck in memory, like the houses created by Le Corbusier in Wißenhof, Stuttgart, and the famous photo of a modern Mercedes in the first plan in front

Imagery in the architectural practice

of the building. Photographs helped architects a lot to communicate their projects to the wide public. It's an instrumentalized mean of communication. For instance, Le Corbusier couldn't find better than such a car to represent his idea of "machine à habiter".



Fig. 3: Photo of the building created by Le Corbusier in weissenhof siedlung, Stuttgart 1927

There's then some bias in photographs. They're not completely objective. Barthes distinguishes *denotation* from *connotation*. In the case of photos, a photo is a non-coded analogon because it doesn't use conventional languages to encode the message with connotated words. Rather, a photo is interpreted differently and individuals

can use different words to describe the same thing. Despite, it may reveal a certain connotation to certain persons. In the example of Le Corbusier, a person who is familiar with his ideas would automatically understand the relation between the building and the car.

Modern architecture has been criticized a lot for a furious ambition to change society and not fitting in with people's culture. This situation was also reflected in photographs. Some studies in the 1970s have revealed the gap that exists between the architects' intentions and the lifestyle of the inhabitants through photographs.³⁴ Although these photographs have been published in architectural magazines, designers questioned the credibility of such critique that is not well-founded in architectural knowledge and that is based on personal impressions. The gap is between architecture as an intellectual phenomenon on one side, and a living place on the other.

In the same period, a new use of photography started to emerge. Instead of using photography to communicate certain ideals behind architecture, photographs have started to be used for a different reason. Until then, the photographs in architectural reviews represented ideal interior spaces with designed furniture and a posing model, mostly female, to represent a modern lifestyle. Renaudie et Gailhoustet were the first to use photography of inhabited interiors to illustrate their architectural approach and the validity of their assumptions. The photo was not used to speak arrogantly about a project, rather to listen to the users and how they use these spaces.

34. District de la région parisienne and Cofremca, *Histoires de cellules*.

Today, it's no more the exception. It's very usual to use inhabited photography in architectural representation.³⁵ The architectural space is revealed through the reality of it being practiced and used in photographs. Eric Lapierre published a critical book on the contemporary architectural production through the lens of photography. He argues that: "for the majority of observers, they [photographs] are the only way to know the [architectural] work."³⁶

For Lapierre, a photograph speaks more to a non-architect than any other image. The plans or section elevations need a minimum technical knowledge, and it's not accessible to everyone. If we want to encourage user participation, we then have to privilege this type of medium and find ways in which it can be used by the designer and the user at the same time.

2.3 Reference photos

As mentioned before, architects constantly take reference and inspiration from other architectural works. In fact, one of the most privileged ways to find relevant references is through architectural photography. Nowadays, all architectural firms use photography to present their work and publish them in architectural reviews or online. This makes it easier to scan for photos a certain type of building, a desired material or other criteria for search.

In the first phases of design, architects need to communicate their ideas effectively and avoid any possible misunderstanding. For this reason, they may use reference photos to precise details in their drafts. When the client compares the drafts and the photos, they can understand the designer's intention by analogy. The architect

35. Debarre, "Quand les architectes exposent des intérieurs habités."

36. Lapierre, *Architecture Du Réel*.

chooses photos that reflect their intentions and how the design should look at the end. They can be relevant in room distribution, exterior spaces, structure, materials..etc. It's a very common method since it makes the projection easier for the client. Despite that, in some cases it's hard to know what exactly in the photo satisfies the client. Which objects is really significant in an image and which are not? When asking such questions to the user, sometimes the answers are not enough because they may have different interpretations.

2.4 Conclusion

As we started in this chapter by the importance of analogical reasoning in architectural practice, and how designers use references in their creative process every day. We then showed how imagery is used by architects in different phases: conception, presentation and feedback.

As we argued in chapter one, the intention was to find a specific type of photographs that are commonly used between the architect and the user. We then find that reference photos offer a lot of potential for creating a successful communication between both sides. They are significant for each participant, and are interpreted differently by each individual. Besides, they simulate a virtual space and enable to estimate the user's behavior. The question is then how to get more meaning out of photos? How to get insight on the subjective representation of each participant?

3 Revealing signification in reference photos through eye tracking

In previous chapters, we studied how built environment is full of symbolic meanings. Signification is produced from the interrelation between the user and the surrounding objects. Then we focused on the photograph, which is an analagon of real built environments. To find a common ground between the architect and the user, the reference photos proved itself as an efficient communication tool. The biggest advantage that reference photos offer is that they are already being used in the architectural practice.

The question here is how to use this visual image to give insight on the participants' subjective representation? In the first chapter, we argued that individual representation can be understood through recurrent patterns in behavior. Instead of surveying every individual, we can detect common patterns of behaviour between different individuals. This way, we relate users to objects and even users to each other. The use of graphs and neural networks can be of great use here, since it can handle big number of participants, like in the example of Pinterest mentioned before.

The potential of reference photos that we are addressing here, is about the visual representation of participant and potential patterns between them. To analyze this process, one may suggest the use of eye tracking technology. Compared to classic surveys, eye tracking is really useful in offering quantitative data in front of an image. How can this technology be useful in architecture? What insight does it give on subjective representation of participants? Can it be easily implemented by architects? In which phase of the design process can it be used?

3.1 Attention-based data

There are a lot of tools that enable eye tracking technology. They can be fixed or portable, in front of a monitor or in real settings, through infrared sensors or normal webcams..etc. The thing in common between all of them is that they are based on fixation points. Fixation point is a two-dimensional point on a scene where the eye movement of an individual stops a while. The experiments that are lead in psychology or marketing argue these are points of attention tell something about the cognitive state of the participant. It may reveal an emotion or a reflection.

Common experiments in marketing design are to analyze where the user looks before making a decision, like clicking on product or making a purchase. Since the technology was used by designers or business psychologists for a long time, the study of fixation points was convenient. The main object of their study is a product, which is an isolated entity, and hence it's logic to search for products that are looked at to predict user behavior. The difference between the marketing and the architectural content is that architecture doesn't have one center of focus. Architecture is not one object, architecture is an assembly of objects.

The attention-based nature of eye tracking in other disciplines has its limits in architecture. As previously mentioned, Gibson argued that being in a space is about an interaction between the individual and everything surrounding. Even if an object is fixed, it's not an isolated perception of the object. The object exists in a context, and hence everything surrounding it is also relevant. The fixation point is part of the central vision which is part of the field of view, whereas peripheral vision plays an important role in our perception as well.

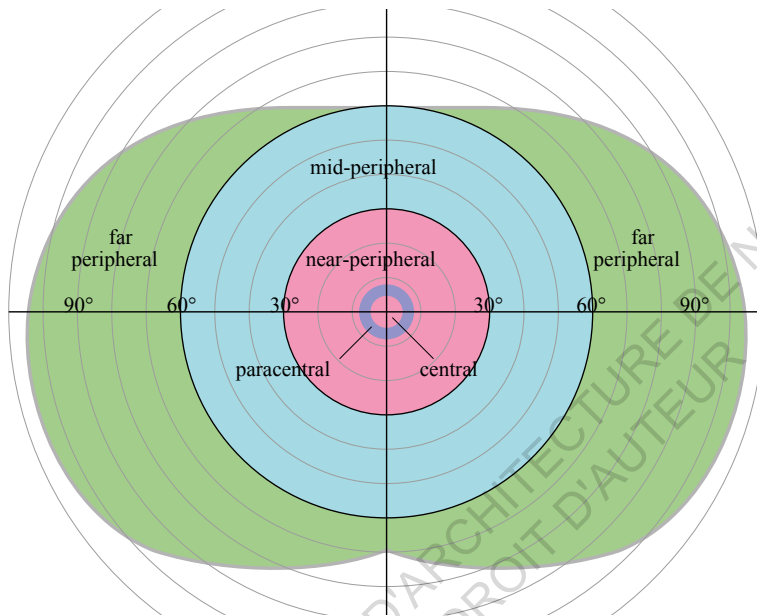


Fig. 4: Field of view

For this reason, when using eye tracking in architectural analysis we should not study only the object, but the surrounding setting as well. The image should not be seen as an object, but rather a array where objects exist. Or even a frame within an array where objects exist. This aspect is important to our experience, because unlike other tools that use recommender systems, the behavior towards an image can't be explained by few elements. Yet a further interpretation should be given to make more meaning of these gaze points.

3.2 Signification of gaze points

Eye movement data is not significant in itself. It's only a non-coded data that should be analyzed and interpreted. In personal surveys, the interviewers ask questions to the participant to understand better their visual behavior. Without these answers, the eye movement

data can have endless interpretations. This method is largely used in visual anthropology and psychology, called a perceptive test. In front of a given stimulus, the answers of the subject are regarded as indicative of the internal state or representation projected by the subject on the studied object. The advantage is that when the interviewer knows where the eye is fixed, they can ask more relevant questions to the subject and then reveal significant qualitative information.

The default of classic projective tests is that it's time-consuming. Since we decided to work on massive participation at first, this method doesn't proof much efficiency. Nonetheless, the combination of quantitative (eye movement data) and qualitative (subject's answers) is of great use. The semantic input of subjects is really important for any data interpretation. But the challenge is to analyze all this semantic input, relate it to the objects and, most of all, relate subjects to one another through these data.

The positivist concept of perception that was presented in the first chapter can be useful here. This idea suggests that objects carry their own meaning, which means that there's some sort of objective reality behind an object. With this understanding, objects should have a structuring semantic information that enables them to be distinguished from other objects. This can be an information related to a physical appearance, a functional role, material,...etc.

3.3 Graph-based data

To achieve such relation between elements, graphs can be used. *Graph databases* are largely used in computing. Given a database of certain elements, they tend to create a relationship between these elements using nodes and edges. In a social network, the nodes may be a set of individuals, and the edges are the friendship relation between each person. Graph representation makes visualization easier, and pattern detection more efficient.

In fact, Christopher Alexander suggested this type of data analysis when laying out the different requirement of a context. In his book "Notes on the synthesis of form", he argued that variables are interconnected with each other, and clusters of closely related elements may occur. Whereas our case is different from Alexander's example, yet this proves potential use of graph representation in the architectural practice.

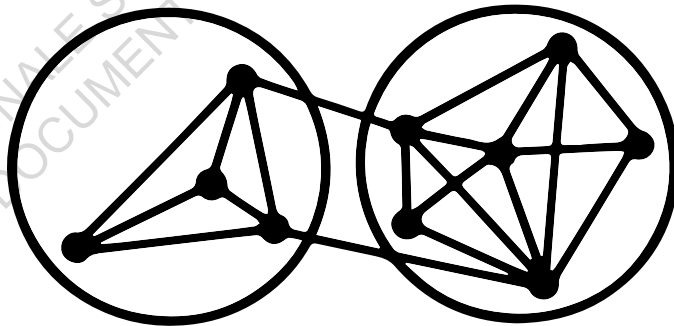


Fig. 5: Christopher Alexander - graph layout of context requirements

3.4 Recommender systems

We now have two information in the study so far. One is the eye tracking data, the other is semantic input. Both are related to each other by a graph network.

These two databases are respectively sequential and non-sequential databases. Both types of data are highly used in neural networks that work on recommendation systems. The advantage of such technology is that there's no need for personal interview. The machine doesn't know why certain individuals like certain things, it only predicts how relevant a content may be and then recommends similar things. And that's where clustering comes into play, like in Alexander's model. People are gathered by some behavior; for example they gave the same tag to the same photo. This results in a *pattern*, and whenever a pattern is detected then it becomes easier to study. Like in Barker's approach, we can understand something about subjectivity by analyzing these patterns. This gives us some insight on the visual representation of subjects, without studying their individual behavior.

Some research has been done on how to use graph databases in architecture. In 2018, a study focused on how to understand the subjective preference of inhabitants in a space.³⁷ To do so, they study the organigram of a place where each room is related to each other by edges if they are directly connected by a door or a stair. Each room has semantic information of its function (bedroom, living room..etc.). Participants were invited to rate each place. A neural network then studies potential patterns, and predicts which type of configuration would a certain participant like.

37. As, Pal, and Basu, "Artificial Intelligence in Architecture."

3.5 A framework for using eye-tracking in architecture

After our precedent research, we find it useful to point out some findings that can be helpful for further implementation. Eye tracking is increasingly used in architectural and urban design as a tool to study human behavior. Many recent research papers have explored its potential in this respect. No doubt these studies enlighten the designer and give critical insight on the built environments. But these studies focused on the brain to solve the subjective representation issue. They work on a micro level, that is keen to explore the individual cognitive experience of space.

We had three criteria since the beginning of this research that we wanted to fulfill. One is that the tool we're studying should be accessible for all participants, regardless to their personal culture. Second, is that it should be convenient for the design process, and can easily be implemented by architects. Third, it should enable massive participation.

For reasons mentioned in previous chapter, reference photos proved convenience for the first and second criteria. Nevertheless, we cannot use high-tech eye tracking devices if we want massive participation. This type of tools can only be used in laboratory, and then restrict the number and the nature of participants significantly. Surely they provide high resolution data, but they impose a big limit on the research.

A new tool for eye tracking that is accessible for everyone is based on webcams. A neural network analyses input photos from webcams and predicts the gaze point at a given time. There is a considerable compromise in data precision, which constitutes a big bias. To reduce this bias, eye tracking data should be crossed with

another input or validated through the process. A good example is “WebGazer.js”. The java-script based application is developed in Brown University and uses normal photos from a webcam. It uses mouse clicks to calibrate the eye movement with the gaze points. We find this tool interesting in our case.

3.5.1 Visual search

As mentioned earlier in this chapter, eye tracking is by nature attention-based. It explores where the eye is fixed. In non-structured interviews, the subject is free to move their gaze on a visual object or in an environment, and then the interviewer ask questions to reveal their cognitive state at that moment. This means that no question or task was demanded before the participant looks at the scene.

When the eye hovers visual information in a scene, it can use two types of gaze orientation. The first is when the eye reacts to stimulus in an automatic and uncontrolled manner, it's called *exogenous orienting*. The other when the eye is fixed voluntary on a goal driven stimulus. Thus, the gaze of the participant is influenced by the task given in the survey.

The issue that eye tracking is attention-based may be solved with a deep understanding of how these two mechanisms work. In our case, we're more interested in a model that is closer to a structured survey. So that in front of a specific photo, the participant should visualize and get to know the visual information first. The eyes then use exogenous orienting, and the resulted eye tracking data are not significant by their own, as argued before. Then participants are asked a question. This question starts a visual search task. Which means that the eye tracking data collected afterwards, are significant in relation to this specific question. This way, the gaze points as

Revealing signification in reference photos through eye tracking

well as fixation points of a participant can be regarded as a significant behavior and are comparable with other participants' behavior. Then, gaze points can be interpreted as selected regions that are relevant to answer this question. And fixation points are zones of hesitation.

We argue that it may be useful to repeat the same exercise for several times with the same participant, so that it starts to become a habit. For example, if we consider the answer of participants in front of nine photographs, then the same question should be asked each time. But there may be another bias, that participant becomes more familiar at the photo number nine than the first photo. That's why shuffling the photos when going through the experiment is recommended.

In a tool like WebGazer, the subject may answer by clicking somewhere on the photo. That's the final answer. The interest of eye movement here is to know where the participant has looked before making this choice. Which hesitations exist? Between which objects?

3.5.2 Quantitative data

3.5.2.1 Segmentation mapping

Since the built environment is about space, the image should be also considered as a three-dimensional space. The eye tracking outputs is two-dimensional, but when laid out on an architectural photograph it has a spatial meaning. To address this issue, each object inside the photo should be separated. To do so, a *segmentation map* should be produced. In a segmentation map, every pixel is labeled and then

Revealing signification in reference photos through eye tracking

belongs to a certain region. This method makes it easier to analyze content. The frequency in which the participant's gaze is placed in a certain region is analyzed, and then informs the amount of attention brought to this object.

3.5.2.2 Spectral gaze points

To reduce the bias produced by the technology chosen (based on webcam) and to give more importance to peripheral vision and to context in which an object exists, the eye tracking data should be considered in a spectral way. This means that beside the fixation point, regions around this point are considered in a concentric way. The center has the highest value, the boundaries have the least.

3.5.2.3 Gaze values

For data analysis purposes, there should be some values attributed to each object in order to make the analysis possible. For example, when the participant is asked, their answer is their gaze. It's an automatically collected data. But the data itself is insignificant, we should interpret this data and create a relation to objects. These objects contain metadata that makes it easier to detect patterns. In the previous example, if in front of nine photos the participant chose recurrently objects with a similar attribute, say a texture, then this may be a pattern that the neural network may detect. The same phenomena can be studied on the macro level with all participants.

Revealing signification in reference photos through eye tracking

The more people look at an object, the more significant the object is for them in response to a given task. Then, when an object lays in the field of view of the subject, it's rated. It gets some score. This score is less important when it's on the peripheral side. But when it's situated many times on the peripheral side, it gets a higher score and then becomes more relevant to data analysis. This score of values is attributed to an object, and not to a pixel.

3.5.3 Qualitative analysis data

As it has been explained several times in this research, we don't opt with person to person surveys to reveal the motivation of users behind their eye movement. Nonetheless, the need for further explanation behind such data is obvious. That's why we tried to search for such tools that don't directly need to interview each user. In fact recommender systems are based on such feedback. Youtube for example uses quick surveys after recommended content to evaluate how good was their system to predict the interest of users in a content. It can be a rating survey. The question here is which type of survey to do in order to get the most insight on the participant's motivation?

Nowadays, hashtags are very common in social media. They are used for many motivations, but one of the most important is the structuring of the published content.³⁸ This means to relate a certain content to a topic, or another content that is similar. It's a semantic index that is coded, and has a signification for its users. Since Twitter made it available on its platform back in 2006, a lot of other social network platforms adopted the same technology. It's becoming essential in our use of social media. We saw how civil movements or marketing campaigns can use a hashtag to get their message

38. Rauschnabel, Sheldon, and Herzfeldt, "What Motivates Users to Hashtag on Social Media?"

through. Its importance is recognized in social sciences, and some researchers use them as databases. Like architectural reference photos, they're already being used in our everyday life and a lot of people relate to them.

In our case, hashtags can be considerably interesting for the interpretation of eye tracking data. In addition, they offer rich data for the graph network and make it more dense. In order to do so, there should be an updated data set of hashtags with every participant's input. This means that participants can choose from hashtags already used, making it more trending. If the participant can't find a relevant hashtag, then they can add their own. But it's preferred to relate to already existing ones to make the experiment more efficient.

3.5.4 Data visualization

With these previous parts, one can build an efficient analysis tool. The experiment is organized around a visual search task, with a precise question. The answer is given by a click from the participant, selecting a certain point in space. Then the participant gives more explanation by choosing or adding a hashtag. Until now, the data can be visualized in different ways. For the participants, if they're interested to discover the relation they may have with other participants, a graph based network may be presented. With participants as nodes and relationship between individuals as edges. Or for architects, a photo can be presented as a heatmap where relevant regions in a photo are pointed out and trending hashtags give complementary explanation to such choices.

Although the system updates itself with each participant's input, it doesn't offer the full potential of its database. It only informs about the participants' behavior and eventually detects patterns, but it doesn't make use of these patterns to recommend more relevant photos. That's where recommender systems can be useful.

3.5.5 Recommender systems

In order to create a successful recommender system, all of the above-mentioned data should be included. The neural network then finds patterns in behavior between elements and can predict new patterns. It's important to organize very well the base datasets, the efficiency of prediction lies on that.

Nevertheless, they are two places where the database requires complementary elements. The database containing photos should be increased. In a small database, the system can run out of content pretty fast, making it hard to suggest new ones. It's then important to enlarge the data set as possible. But this comes with another difficulty. How to segment every photo in a large data set? And that's the second place where the database needs more work. Every element should be segmented, and attributed with metadata. This process can be automated, but a certain amount of error is to be considered.

The use of recommendation system may be very useful for efficient communication in participatory design. Like in Pinterest, people may be able to express non-verbal needs and desires. Starting with one question, a query, the recommender system can continue to suggest more and more relevant photos until finding exactly the setting that the user is looking for.

Conclusion

In the beginning of this research, we were keen to decode the subjective representation of space. This question proved its relevance in the field of participatory design, to enable symbolic justice and to avoid dominant signification which may support a certain social or cultural order. The semiotic view was necessary to understand the notion of cultural codes, and how they're critical in the perception process. We focused on the study of visual perception, and how visual stimulus play an important role in how individuals interpret a space and see affordances. To avoid possible complexity in studying the cognitive activity of each user, we preferred an ecological approach. Authors like Christopher Alexander and Roger Barker suggested that patterns in behavior may emerge in relation to certain environmental settings. This concept made it easier for us to study the subjective representation on a bigger scale, enabling a bigger number of participants in the experimental models.

To find relevant visual tools in the architectural practice, we studied the place of imagery in the design process. Out of many visual elements that are used by architects in conception, communication or feedback, we chose reference photos as a potential mean of communication between architects and users. These photos enable an efficient dialog between two different publics, and are accessible to everyone which makes it easier to implement in the design process afterwards. They're considered as analogon of real environments, with their ability to simulate existing settings. They hold the signification of objects in real environments, and hence can inform us on the cultural codes through which participants perceive the environment.

Conclusion

In the last chapter, we study furthermore the reference photos as significant elements and see how eye tracking can be useful to reveal individual signification of the architectural space. The photograph is used as stimuli to reveal individual representations. Similarly to projective tests in psychology, semantic answers are collected to evaluate the behavior of the participant to a given photo. We studied hashtags as frequent mean of communication nowadays and explore how they can enable the detection of patterns within participants. This semantic information serves as an input to a recommender system which put participants and objects in connection through graphs. These tools prove potential application in subjective data visualization which can give social insights to architects through the design process.

This research can be considered as a premise for further implementation of the eye tracking technology in architectural design, and specifically in participatory design. The framework proposed can be examined in contexts where a big number of individuals are concerned by a design. The hypothesis in the last chapter that patterns of predictability may emerge should be confronted to practice, and to the feedback of users.

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Figures

Fig. 1: Diagoon Experimental Housing in Delft by Herman Hertzberger 1971	16
Fig. 2: Wine tower in Alhambra, Granada. Photo by: Charles Clifford in 1854	25
Fig. 3: Photo of the building created by Le Corbusier in weissenhof siedlung, Stuttgart 1927	30
Fig. 4: Field of view	36
Fig. 5: Christopher Alexander - graph layout of context requirements.	38

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