AI EDAM

Artificial Intelligence for Engineering Design, Analysis and Manufacturing

CAMBRIDGE UNIVERSITY PRESS

THE IMPACT OF ARCHITECTURAL REPRESENTATIONS ON CONVEYING DESIGN INTENT

Journal:	*Artificial Intelligence for Engineering Design, Analysis and Manufacturing*
Manuscript ID:	Draft
Manuscript Type:	Research Paper
Date Submitted by the Author:	n/a
Complete List of Authors:	Cunin, Maxime; University of Liège, Faculty of Engineering Sciences Yang, Maria; MIT, Mechanical Eng and Eng Systems Elsen, Catherine; University of Liège, Faculty of Engineering Sciences
Keyword:	Architectural design, Design cognition, Design theory

THE IMPACT OF ARCHITECTURAL REPRESENTATIONS ON CONVEYING DESIGN INTENT

MAXIME CUNIN[1], MARIA C. YANG[2] and CATHERINE ELSEN[1]

[1] *University of Liège, Belgium*
[catherine.elsen@ulg.ac.be ; maxime.cunin@alumni.ulg.ac.be]
1 chemin des Chevreuils – BAT 52
B4000 Liège – Belgium
Phone : +32 4 366 92 42

[2] *Massachusetts Institute of Technology, USA*
[mcyang@mit.edu]
77 Massachusetts Avenue – 3-446
02139 Cambridge, MA – USA
Phone : +1 617 324 4029

IMPACTS OF ARCHITECTURAL REPRESENTATIONS (short version)

Number of manuscript pages / **18** pages
Number of tables / **4** tables
Number of images / **8** images

THE IMPACT OF ARCHITECTURAL REPRESENTATIONS ON CONVEYING DESIGN INTENT

MAXIME CUNIN[1], MARIA C. YANG[2] and CATHERINE ELSEN[1]

[1] *University of Liège, Belgium*
[2] *Massachusetts Institute of Technology, USA*

Architects express themselves graphically in order to communicate ideas both to clients and to themselves. In practice, they rely on a variety of representations such as free-hand drawings, 3D computer rendered images, and photomontages to convey their design intent. Research to date has demonstrated differences and commonalities in the ways in which expert designers and laymen perceive visual understanding. It is still unclear how architects themselves use different types of representations to express different intentions, and how accurately their expected audience perceives those intentions.

The purpose of this research is to investigate how laymen interpret the initial design intent of an architect's design, and what role different forms of representations play in this process of understanding a design.

This paper describes a five-step process for developing a survey that was used to gather data from 686 laymen respondents. It was found that certain types of simpler representations presented in specific contexts are unexpectedly found to be a more efficient way to faithfully transmit an architectural intent.

Keywords
design intent, design communication, external representation, architectural conception

1. CONTEXTS and STATE-OF-THE-ART

The architectural design process can often be characterized by the visual representations that it generates, whether created for internal or external use, used by an individual or collectively, and represented graphically, physically or numerically, among other aspects. In particular, external representations play an essential role translating architectural design intent, or the theme that an architect is trying to convey in a building, into a graphical representation. Such graphical representations have been variously described in the literature as “mediator”, “intermediate”, or “boundary” objects. Studies have recently explored the challenges of transmitting intent in both in industrial design and in architecture as a collaborative process among design experts (Elsen, Darses and Leclercq, 2013; Sutera, Yang and Elsen, 2014). This article considers the impacts of external representations on laymen who play a key role in the eventual success of a building, but have no insight into the architect’s conception of a design. Two design contexts illustrate such situations, more and more frequent: the architectural competition and the relationship between architect and client. During architectural competitions, architectural firms try to gain recognition, and as such they put great effort into creating successful submissions through detailed representations. In such competitions, architects submit one or more architectural concepts to a panel of judges. Each concept is typically represented by a variety of visual forms. Likewise, in the contractual relationship between an architect and his clients, the architect chooses to communicate early phase designs by sketches, and sometimes by 3D representations or physical models.

The choice of an external representation and its quality are important. Its form, its content, and its function can all heavily impact the understanding and evaluation of architectural projects during the conceptual design process (Détienne et al., 2007; Bates-Brkljac, 2008; Pei et al., 2011). An external representation may be notional rather than realistic, with the goal of communicating a design’s symbolism, its aesthetic, or its importance with respect to evaluation criteria (Summers and Shah, 2004). The architect makes choices about how to externally represent a design under the assumption that the non-expert external viewer is able to read and understand precisely the symbolic content and to extrapolate the design metaphor, though sometimes this assumption is incorrect (Wergles et Muhar, 2009). Different representations may be created throughout the design process and architects particularly pay attention to the form of their externalizations, adapting this form of representation to the state of progress of the project. Highly symbolic and rough sketches presented in an early phase enable the viewer to focus on key architectural choices without getting mired prematurely in superficial details. On the other hand, a photorealistic three-dimensional representation shown in a later phase will encourage the viewer to examine other aspects of the design, and perhaps also crystallize aspects of the project for which the architect would have less flexibility in changing at later stage (Harrilchak, 1993).

Several researchers have investigated how non-experts respond to different features of representations. The *credibility* of external representations has been studied, which tends to change in relation to a representation's abstraction, accuracy, realism or visual clarity. A representation's *faithfulness* has been studied extensively, in particular during the first implementations of CAD representations, which have been compared to their first analogical counterpart. Levels of detail, view angles, surface textures, movements, management of shadows and so on are considered as potential factors in creating a *faithful,* or realistic representation (Oh, 1994; Lange, 2001; Rohrmann and Bishop, 2002; Wergles and Muhar, 2009). For disciplines such as industrial and product design, visual perception plays an even more important role for the selection of artifacts. Researchers have examined the perception of the *customer* or *user*, examining how *faithfulness* or *credibility* are connected with complex questions such as desirability (Crilly, Moultrie and Clarkson, 2004 ; Macomber and Yang, 2011). Petiot and Yannou (2004) formulated predictive criteria that led to *semantic attributes* of a representation, while the emotional dimensions of a design have been discussed by Norman (2005).

In architecture, several researchers have tried to understand how tools frequently used in practice (hand-drawing, CAD model, 3D photomontage or physical prototypes) influence the perception and evaluation of the architectural artifact (Table 1). Inspired by research in other fields, they have considered the impacts of abstraction, accuracy, realism, familiarity or emotional perception. It is important to note that many of these results rely highly on the project type, the context or the demographic of the viewers.

Surprisingly, there is limited research that highlights the influence of external representations on the communication of *architectural intent* from the architect to the non-expert viewer.

Authors	Purpose	Characteristics evaluated	Media			
			Hand drawing	CAD Model	Photo-montage	Picture
Bates-Brkljac (2007)	Representations effectiveness	Accuracy, realism, abstraction.	●	●	●	
Day (2002)	Determine best practice.	Accuracy, realism, abstraction.		●	●	
Bishop et al. (2003)	Comparison of reality vs. computer-simulation.	Quality, comprehension, realism, appreciation.		●		●
Wergles & Muhar (2009)	Comparison of reality vs. computer-simulation.	Perceptual impression, perception, retention, comprehension, deduction.		●		●
Oh (1994)	Computer simulations effectiveness in portraying reality: wire frame, surface model, image processing, and collage.	Visual attractiveness, confidence, site familiarity, emotional perception.		●	●	●
Lange (2001)	Validity of virtual representation to represent reality.	Realism.			●	●
Meitner (2004)	Influence of angle of view.	Scenic beauty.				●
Rohrmann and Bishop (2002)	Influences of simulation characteristics: day time, shadows, weather.	Quality, readability, realism, appreciation.		●	●	
Brown and Gifford (2001)	Architects' prediction of lay people perception.	Emotional perception.				●
Llinares and Page (2007)	Identify main attributes to quantify clients' perception.	Emotional perception.			●	●

Table 1 - *Summary of previous studies on architectural representations - Purpose, evaluated characteristics, studied media.*

2. RESEARCH QUESTION

The efficient communication of architectural design intent, as imagined by the architect, appears to be a key factor in how non-experts perceive a design. Non-experts play an increasingly important crucial role in many architectural decision-making processes. In architecture, numerous studies have been conducted about the impacts of representations on lay-people. However, this research has mainly focused on the definition of predictive and differentiating factors in a *credible* or *faithful* representation. The present article aims to complete this approach by focusing on the impacts of external representations commonly used in architecture practice. How do representations shape the perception of key factors of an architectural intent? How efficiently does each representation, consciously created by the architects, communicate the primary intent of the architect? What elements of architectural intent can be communicated visually?

3. METHODOLOGY

3.1 Construction of the online survey

In order to answer these research questions, a survey was created to collect data on perception of design intent. An online survey was created in four steps through Qualtrics and distributed through the web platform "Amazon Mechanical Turk" (Figure 1).

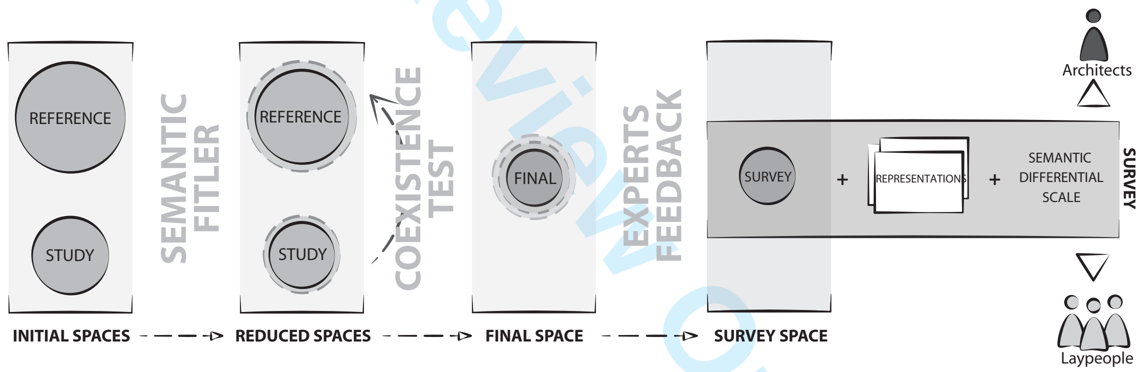

Fig. 1 – *Scheme of the methodology adopted to generate the online survey.*

Architectural representations. The **first step** was to collect multiple representations of projects from 16 architects, along with a project description (in written form or transcribed from in-person interviews) of the main architectural intent of the project (academic, real-size or from competition contexts). We asked both students (6) and professionals (10) for representations to reflect the full range of practice including traditional tools such as hand sketching and newer digital techniques. Representations were sorted and fell into 3 natural categories: sketches and hand-drawings; basic digital models, such as "Sketchup" and CAD models; and photorealistic renderings. These project representations were chosen both because of their diversity of architectural typology and their similar point of view - avoiding effects described in Meitner (2004). A sample of the 16 projects chosen for this study is shown in Figure 2: "hand-drawing", "CAD model" and "rendering". CAD models and renderings are similar in that they are both digital, but renderings tend to include much greater detail and take longer to generate[1].

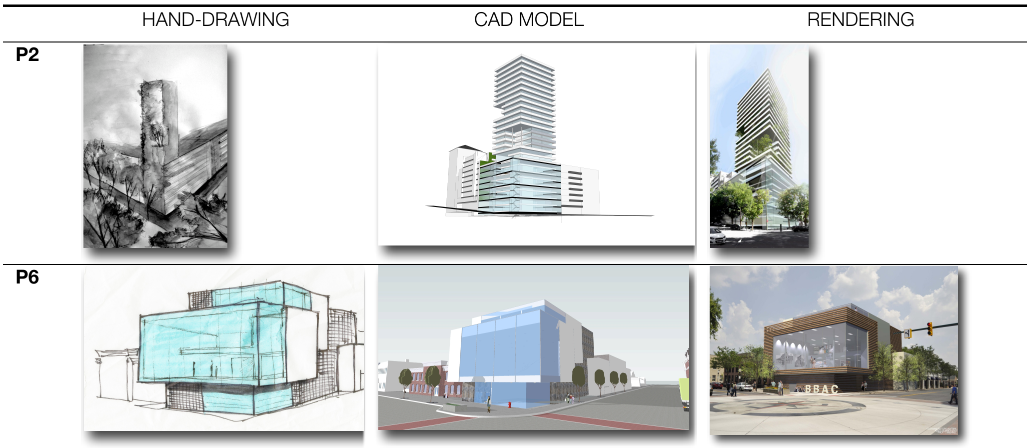

Fig. 2 – *Two example sets of representations. Each set is of one building visually represented in three ways: as a hand drawing, a digital ("CAD") model, and a more detailed digital rendering.*

Architectural intent. The use of adjectives to describe architectural intent has been observed by Alcantara et al. (2005) and Artacho-Ramirez (2008). To enable survey respondents describe the architectural intent of a particular image, we decided to present them with pairs of synonyms and antonyms that architects themselves use to describe their projects. **The second step** was therefore to determine a representative enough space of adjectives that could be used to define architectural intent, we started with a large pool of adjectives and successfully winnowed them into a small, tractable set that was still representative of the space of architectural terms (cfr. Figure 1). Adjectives were drawn from two different sources. The first was an "initial study space" including 90 adjectives and qualifiers, such as "verticality", "integrity" or "monolithic", collected through the architects' own descriptions of their 16 projects. The second was a much larger "initial reference space" including 287 adjectives collected from the analysis of 460 architectural project descriptions found in architecture magazines, websites and portfolios (421 students' and 39 professionals' projects). We then compared these two sets of adjectives in order to ensure representativeness of the collected adjectives. At this stage, we observed that there was a strong distinction between adjectives from expert architects (with several years' experience) and younger architects or recently graduated. Word choice seemed to become more complex or abstract with expertise.

The two sets of "initial" adjectives were re-organized and semantically filtered under a set of criteria defined by Kuller (1975) and Jindo et al. (1995). Antonyms and synonyms were paired; qualifiers relating to specifics of a project were filtered out (for instance, "inside vaulted space" or "breathing space"), as well as adjectives relating to judgment of value. The *initial study space* was then reduced to 28 groups of synonyms and antonyms, while the *initial reference space* was reduced to 51 groups. The intersection of 20 groups of unpaired synonyms and antonyms between the two initial spaces was considered reasonably representative of the space of architectural

[1] The participating architects were asked to estimate the time required to produce each image. On average, it took them 10 minutes to produce the hand-drawing, 300 minutes for CAD and 800 minutes for rendering.

language and was used to build the “final semantical space”. Individually, eight expert designers and architects studied the unpaired antonym and synonym groups and selected only one pair of adjectives for each group. These selected synonym/antonym pairs were then compared until a consensus was reached. The “survey space” was finally created and included 20 pairs of synonym/antonym pairs, called attributes, for instance “quiet / noisy”, “modest / audacious” (cfr. Annex 1).

Survey creation. The **third step** of the methodology consisted of building the survey. A 5-point Likert scale was chosen, and more specifically the “semantic differential scale” developed by Osgood et al. (1957). This scale (see Annex 1) distributes the adjectives from each bipolar couple in each of its extremity. Therefore, it limits the biasing effects and interpersonal differences in the linguistic understanding of certain words[2] (Alcantara et al., 2005).

Collect survey data. Once the survey built, the **fourth step** consisted in submitting it to 880 survey takers, the workers of the Amazon Mechanical Turk[3] (called “ Turkers ”). The survey was limited to Turkers working in the United States and with at least 95% previously accepted participation in other Mechanical Turk studies. Each Turker is monetarily compensated for his or her participation to the study. The representation database included 48 representations: one hand drawing, one CAD model and one photorealistic rendering for each of the 16 projects. Each Turker was shown a hand drawing, a CAD model, and a rendering randomly chosen from this database, and was asked to evaluate each one (through the semantic differential scale) on basis of the 20 attributes. The hand drawing, CAD model and rendering shown to each Turker were related to different projects, in order to avoid inter-project comparisons. Demographic questions were asked at the end of the survey, to avoid biases that might occur if placed at the beginning of the survey.

The architect’s own assessment of intent. Of the 16 projects, we had direct (front-to-front) access to 6 of the original architects. To assess the creator architect’s original intent for a project, these 6 architects were also asked to complete the survey. The only difference is that they were asked to evaluate only representations of their own project. First, the semantic scale was shown to them along with the three representations at once. The architects’ intent was determined by their responses to the 20 attribute ratings. They were asked to choose the neutral point between the synonym/antonym pair if the attribute was not part of the initial architectural intent. Second, they were asked to rate the three representations individually so as to consider their initial intent as it related specifically to the representation itself.

3.2 Analysis methods

Survey responses from Turkers were vetted to ensure that they were legitimate. Surveys were rejected for the following reasons: they were completed in less than 3 minutes (valid surveys took 7 min, 1 sec on average), responses were repetitive (same responses all questions), or repeat survey

[2] The opposite of “Light” could be “Dark” and/or “Heavy”. The sentence “I find this building light” is ambiguous and could lead to mistakes in processing the data.

[3] See http://aws.amazon.com/fr/mturk/

takers (duplicate IP addresses). Of the original 880 survey takers, only 686 responses (78%) were considered valid.

The Kruskall-Wallis and Mann-Whitney tests for non-parametric populations were chosen to detect statistically significant differences between pairs of representations and to differentiate the direction of the influence. The statistical distribution of the results can be approximated by a χ^2 ($\alpha < 0.05$).

4. RESULTS

For this paper, we decided to focus on architects' expression of intentionality, and internal coherency in expressing architectural intents. Therefore, we only report data and results related to the 6 of the 16 projects for which we had a direct access to the architect creator of the project and his/her representations, that is 6 architects (3 students; 3 professionals) that could in person answer our questions and surveys concerning their intents. The number of collected semantical scales is reported in Table 2, for each project and for each type of representation. In total, 790 scales (ranking 20 attributes each) were collected. The results summarized in this section successively present results in regard to the different attributes, to the three types of representations and finally to the inconsistencies that architects themselves expressed when asked to evaluate their project as a whole, and then for each of their representations separately.

	Hand-drawing	CAD model	Rendering	TOTAL
P1	43	43	44	**130**
P2	43	43	43	**129**
P3	45	44	48	**137**
P4	43	42	46	**131**
P5	43	44	42	**129**
P6	44	44	46	**134**
TOTAL	**261**	**260**	**269**	**790**
MIN - MAX	**43 - 45**	**42 - 44**	**42 - 48**	**129- 134**

Table 2 – *Number of scales collected (*20 attributes), per project and per representation.*

4.1 Analysis per attribute

The Figure 3 below compares lay-people's perception of the initial architectural intent, per attribute. Each of the 6 architects had to rate his or her own three representations, so each of the 20 attributes has been evaluated 18 times (y axis). In some cases, the architects opted for the neutral point of the semantical scale, as they didn't have a specific intent for this attribute. This explains why some bars of the chart are shorter than others, such as for the attributes A3 ("hard/soft") and A16 ("small/large") (see Figure 3).

Some attributes selected by the architects were differently perceived by the evaluators. The second reading of this graph consequently stands in the ratio of the successfully conveyed intents (in dark) over the number total of intended attributes (whole bar, light grey). The fact that architects obviously lacked interest for some attributes (small light grey bar) doesn't necessarily mean a high(er) level of disagreement amongst the non-expert raters. In other words, architects not willing or not interested in conveying a certain intent cannot be sure that non-experts raters will not see that specific intent in the representation.

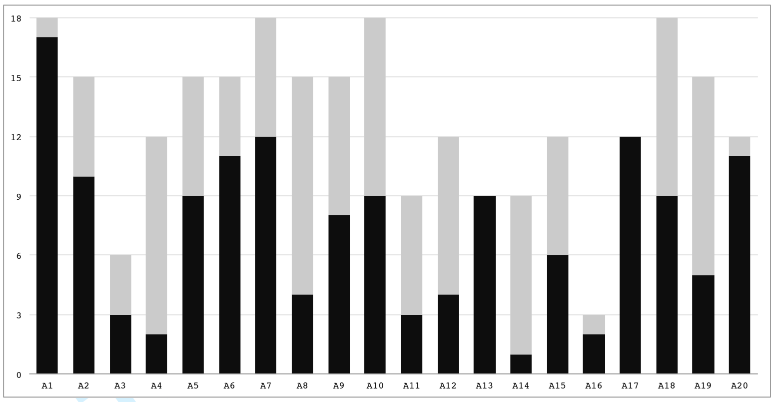

Fig. 3 – *Ratio between the successfully conveyed intent (regarding the initial intent of the architect - in black) and the representations differently perceived (in grey), per attribute.*

The attributes A1 (“contemporary/classical”), A13 (“low/high”), A17 (“vertical/horizontal”) and A20 (“common/unique”) had the highest ratios. Each time the architect wanted to convey an intent related to these attributes, lay-people generally perceived them as intended. In contrast, the attributes A4 (“robust/delicate”) and A14 (“composite/monolithic”) were wrongly perceived by viewers most of the time. One possible reason for this are the ways such terms are perceived by different communities – the way an architect thinks of something “delicate” may be quite different from what a lay person thinks of as “delicate.” Another possible reason is that the representations do not adequately convey these particular intents.

We can also analyze the results project by project. Second column of Table 3 summarizes the “level of interest” architects had for the attributes: each architect expressed his/her initial intents through the 20 attributes for each of the three representations, that is a total of 60 evaluations. The architect of project 1 (P1) for instance expressed interest for 54 attributes, which means only 6 attributes were rated as “neutral”, i.e. “not initially intended”. Third column represents the “level of success”, i.e. the number of attributes that were actually perceived by the lay-people as initially intended by the architects. The last column shows the ratio “#success/#interest” in terms of transferring attributes. Interestingly, the level of success is not correlated to the number of attributes initially intended by the architects. That might indicate that architects tend to exaggeratedly think their projects convey intents that are nevertheless not successfully captured in their representations.

	# interest	# success	Q
P1	54	30	0.56
P2	33	24	0.73
P3	39	20	0.51
P4	45	22	0.49
P5	45	26	0.58
P6	42	25	0.60

Table 3 – *Ratio (Q) of the successfully conveyed intents (# success), over the number of initially intended attributes (# interest), per project.*

4.2 Analysis per representation

Data was analyzed per type of representation (Figure 4). The average ("AVG") shows that the level of success in the communication of attributes was slightly higher for photorealistic renderings, but closer inspection shows that only 3 over the 6 projects actually follow this trend. The projects P2 and P6 (represented in Figure 6) present different trends, especially in regard to CAD models. The CAD model from the project P6 does not seem to efficiently convey the initial intents in comparison to the two other representations. In contrast, for the project P2, it is the CAD model that most efficiently conveys the architect's intents.

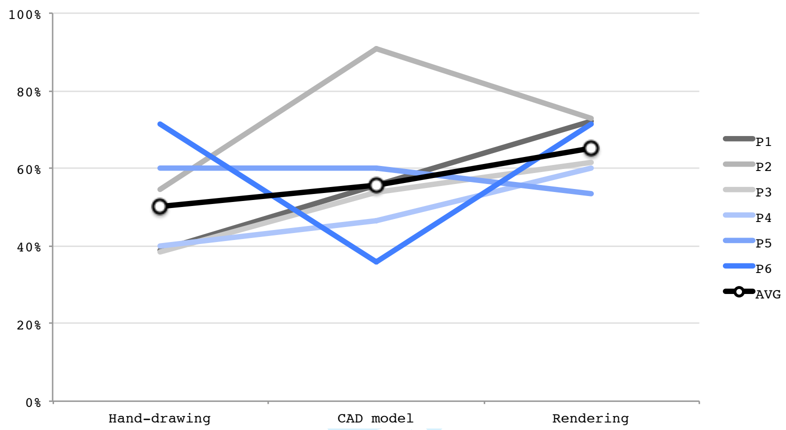

Fig. 4 – *Ratio (in %) of the number of successfully conveyed attributes over the number of intended attributes by the architect.*

4.3 Architects' Inconsistencies

As noted in this paper, the architects evaluated their own representations twice, once as a group of all 3 representations ("global") and once for each representation individually ("individual"). How consistent is the architect when s/he evaluates his or her own project globally vs individually? Figure 5 summarizes the inconsistencies found by comparing the "global" intents with the intents expressed per representation. The light blue bars are the number of inconsistencies (i.e. non-consistent ratings) in the architects' evaluations (global vs. individual). The bright blue bars represent the proportion of architects' inconsistencies that are statistically significantly differently perceived by the external raters. Finally, the black bars represent the total number of attributes statistically significantly differently perceived by the evaluators, without any particular consideration of for the architects' judgments. It is interesting to note that there is no clear influence of architects' incoherently rating attributes over on the lay-people's perception, when we compare inconsistencies proportions from a project to another (in bright blue). In other words, if an architect demonstrates variable intents in evaluating his/her own representations (or simply recognizes that his/her representations convey variable intents), it does not necessarily mean that lay-people will be inconsistent as well, or capture those inconsistencies. Moreover, there is no correlation between the number of architects' inconsistencies (in light blue) and the total number of lay-people's inconsistencies (in black). In the projects P3, P5 and P6, the architects' inconsistencies are even stronger than those of the lay-people's, who are more consistent than the architect him/herself.

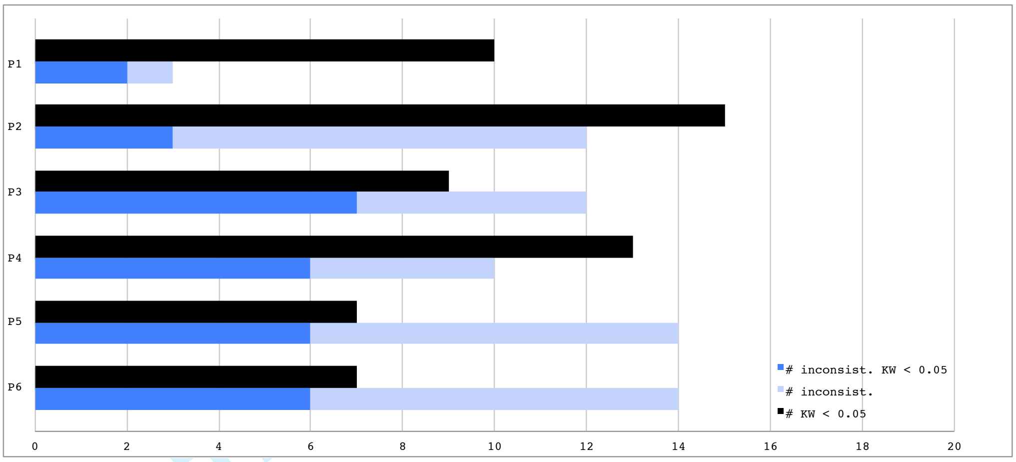

Fig. 5 – *In light blue: number of inconsistencies made by architects themselves. In bright blue: proportion, related to these architects' inconsistencies, of the number of statistically significant inconsistencies in regard of external ratings. In black: total number of attributes statistically significantly differently perceived by the external raters.*

Figures 6, 7 and 8 detail these results by analyzing the differences between pairs of representations – hand drawing and CAD, CAD and renderings, and hand drawing and renderings.

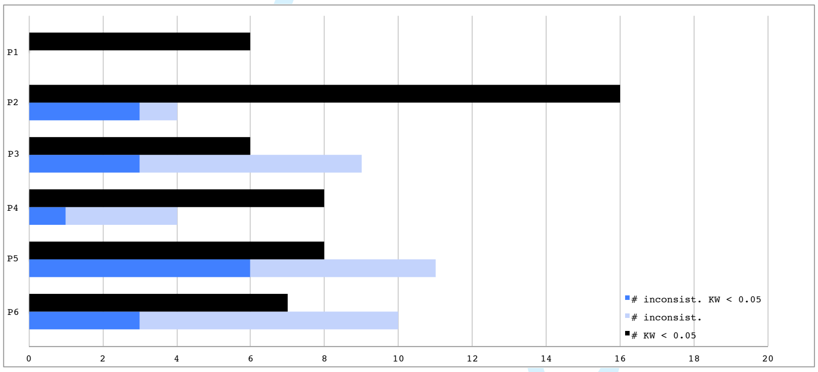

Fig. 6– *Comparison between hand-drawings and CAD models. In light blue: number of inconsistencies made by architects themselves. In bright blue: proportion, related to these architects' inconsistencies, of the number of statistically significant inconsistencies in regard of external ratings. In black: total number of attributes statistically significantly differently perceived by the external raters.*

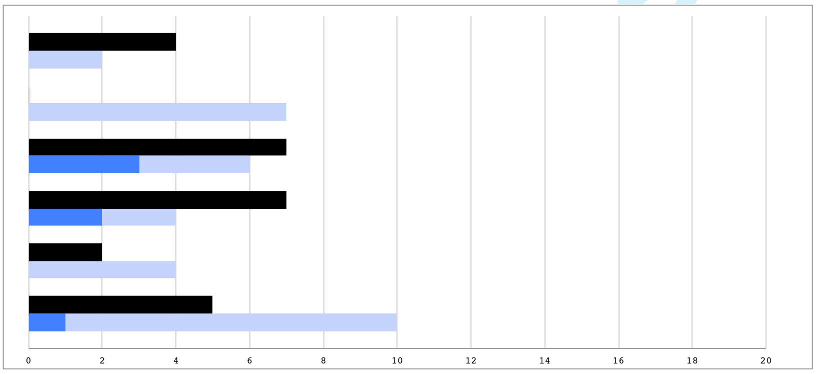

Fig. 7 – *Comparison between CAD models and renderings. Legend: cfr. Fig. 6.*

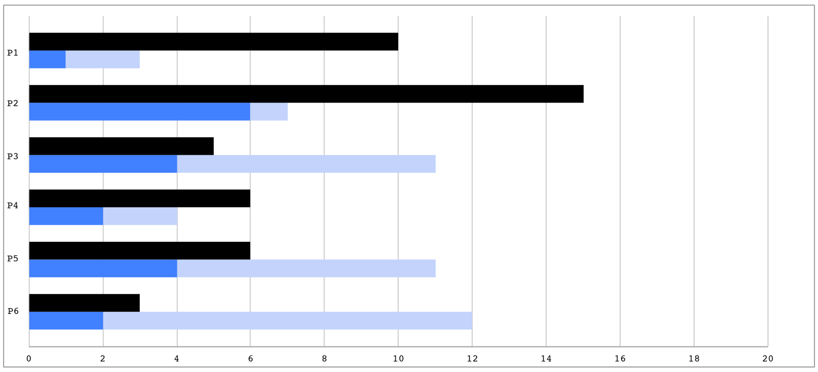

Fig. 8 – *Comparison between hand-drawings and renderings. Legend: cfr. Fig. 6.*

This analysis allows us to highlight architects' inconsistencies (in light blue) across representation types. For 4 of the 6 projects, there are fewer inconsistencies between hand drawings and CAD models than with the other pairs of representations. For these projects, the architects tended to maintain the same architectural intent in their hand drawing as in their CAD model. However, when we examine the attributes differently perceived by the lay-people (in black), CAD models and photorealistic renderings tended to be rated most consistently. From a lay person's point of view, this makes sense. The viewer would not be expected to consider the design process in assessing a representation – to them, the representations are simply images. However, the higher fidelity an image is, the more clearly and consistently one would expect them to perceive intent. Thus, perceptions between the two higher fidelity representations, CAD and rendering, could be expected to be more consistent with each other than when paired with lower fidelity hand drawings. In summary, for the architects, hand drawings and CAD models appear to communicate similar intents, while instead CAD models and photorealistic renderings rather do so for the lay-people.

The same analysis can be conducted by attribute per attribute. Figure 3 revealed that the attributes A4 ("robust/delicate") and A14 ("composite/monolithic") were incorrectly perceived by the evaluators most of the time. However, these two attributes were generally similarly evaluated by lay-people for all three representations: evaluations vary from one representation to another only 21% for A1 and 15% for A14. That means that representations communicate relatively constantly the intent to lay-people, even if it is not in the way initially intended by the architect.

Some attributes were routinely intended by the architects, but yet in a different manner from one representation to another. In particular, attribute A7 ("dynamic/static") was intended by all the architects for all (18 of 18) of their representations, but in an inconsistently manner (inconsistencies between CAD model and rendering for 4 of the 6 architects; inconsistencies between hand drawing and rendering for 5 of the 6 architects). Additionally, the examination of the data reveals an important difference of perception from the viewpoint of the lay-people (for 57% of the projects). In this case, architects encountered difficulties in coherently assessing their representations, this post-evaluation inconsistencies coinciding with lay-people difficulties to agree on the intent perception.

5. DISCUSSIONS and CONCLUSION

Opposing pairs of adjectives (attributes) were carefully consolidated through a series of distinct steps (see section 3.1 Construction of the online survey), starting with a pool of 377 adjectives collected from 476 architectural documents and project descriptions. A total of 686 layperson assessments of 6 architectural projects were collected through an online survey. The detection of inconsistencies between the attributes intended by architects and the attributes perceived by lay people showed that some architectural intentions (A4 "robust/delicate" and A14 "composite/monolithic") seemed to be particularly difficult to communicate to lay-people via the representations, as they were perceived as the opposite of the architect's initial intent. In this particular case, this discrepancy might be explained by the limitations of the representation – the sense of materiality and massiveness of the attributes are particularly difficult to convey with a sketch, CAD or rendering. More broadly, it seems then that some architectural intentions are not equally communicable graphically. The present study is limited to the analysis of external representations, focusing on the communication of visual attributes as seen in the everyday life via advertising or public inquiry for instance. Future work might investigate the impact of other modalities for communicating about an architectural project, such as verbal or gestural, for instance.

Differences in types of representation. This study suggests that simple 3D CAD models and the photorealistic renderings, though much longer and more challenging to build, are more efficient at conveying the key factors of an architectural intent than a hand drawing (perhaps because lay-people less often encounter such hand drawings). Photorealistic renderings are linked to being slightly more efficient at conveying the initial intentions, however this difference is not statistically significant. In other words, the efficient communication of an architectural intent within the design decision-making process (and not the post-communication process) is easily satisfied by a representation that requires in average 60% less of time investment than a photorealistic rendering (Table 4). In that respect, we are in agreement with previous results in urban design from Pietsch (2000) and Radford et al. (1997) who recommend developing fast and less realistic computer models for a just as efficient communication.

Finally, we end this discussion by noting that the architects themselves sometimes were inconsistent in matching the global intents of their project with the intents conveyed by each of the individual representations of their project. This might be explained by a cognitive distance that unconsciously divides, little by little, the first strong intents of a project and their translation into the final external representations, resulting from successive transformations of the project. This might also be explained by an architect's reflections on his/her own work over time, as he or she re-evaluates the images created and perhaps is not as satisfied with he/she had previously been. Whatever the hypothesis, it should be noted that the perception of the lay-people of a particular attribute is often independent of the perception of the architects, and sometimes even opposite. The image itself may shape the perception of key factors of an architectural intent, and sometimes independently of any will of the architect. We still have to envisage a mediation form that can more accurately express a complex architectural intent so that users will perceive them correctly.

'**A**' is ... compared to '**B**'

	B **Hand-drawing**	B **CAD Model**	B **Rendering**
A **Hand-drawing**	-	-	-
A **CAD Model**	- mostly differently perceived - more clear - mostly as disagreed on as - more successfully conveying an intent	-	-
A **Rendering**	- mostly differently perceived - more clear - mostly as disagreed on as - more successfully conveying an intent	- rarely differently perceived - as clear - as disagreed on as - more successfully conveying an intent	-

Table 4 – *Comparison of the three representations evaluated in this study.*

Bibliography

Alcantara, E., Artacho, M.A., Gonzalez, J.C., & Garcia, A.C. (2005). Application of product semantics to footwear design. Part I - Identification of footwear semantic space applying differential semantics. *International Journal of Industrial Ergonomics*, 35(8), 713–725.

Appleyard, D. (1977). Understanding professional media: issues, theory and a research agenda. *Human Behavior and Environment*, 1, Plenum Press, New York, USA, 43-88.

Artacho-Ramirez, M.A., Diego-Mas, J.A. & Alcaide-Marzal, J. (2008). Influence of the mode of graphical representation on the perception of product aesthetic and emotional features: An exploratory study. *International Journal of Industrial Ergonomics,* 3(11), 942-952.

Bates-Brkljac, N. (2007). Investigating perceptual responses and shared understanding of architectural design ideas when communicated through different forms of visual representations. In *International Conference Information Visualization*, Zurich, SW, 348-353.

Bates-Brkljac, N. (2008). Towards client-focused architectural representations as a facilitator for improved design decision-making process. In: Timmermans, H.J.P., de Vries, B. (*eds.*): *Design & Decision Support Systems in Architecture and Urban Planning*, University of Technology Eindhoven, Eindhoven, NL.

Bluman, A.G. (2009). Elementary statistics : a step by step approach. 7th editions, McGraw-Hill Higher Education (*Publisher*), Boston, USA.

Brown, G., & Gifford, R. (2001). Architects predict lay evaluations of large contemporary buildings: Whose conceptual properties? *Journal of Environmental Psychology*, 21(1), 93-99.

Crilly, N., Moultrie, J., & Clarkson, P. J. (2004). Seeing things: consumer response to the visual domain in product design. *Design Studies*, 25(6), 547-577.

Day, A. (2002). Urban visualization and public inquiries: the case of the Heron Tower. *Architectural research quarterly,* London, UK, 363-372.

Détienne, F., Visser, W., & Tabary, R. (2006). Articulation des dimensions graphico-gestuelle et verbale dans l'analyse de la conception collaborative. *Psychologie de l'Interaction*, 21-22, 283-307.

Elsen, C., Darses, F., & Leclercq, P. (2013). La graphique de l'intention : transfert et appropriation d'intentions graphiques en collaboration. *Interfaces Numériques*, 2(2), 489-508.

Harrilchak, M.A. (1993). The affect of rendering techniques on the evaluation of computer generated design simulations. *Master's thesis*, College of Environmental Science and Forestry, State University of New York, Syracuse, New York, USA.

Jindo, T., Hirasago, K., & Nagamachi, M. (1995). Development of a design support system for office chairs using 3-D graphics. *International Journal of Industrial Ergonomics,* 15(1), 49-62.

Kuller, R. (1975). Semantisk miljo¨ beskrivning (SMB). Psykologiforlaget, Stockholm, SE.

Lange, E. (2001). The limits of realism: perception of virtual landscapes. *Landscape Urban Planning*, 54(1-4), 163-182.

Levine, D.M., Berenson, M.L., & Krehbiel, T. C. (2008). Statistics for Managers Using Microsoft Excel. Fifth Edition, Pearson Education (*Eds.*), Prentice Hall (*Publisher*), New Jersey, USA.

Llinares, C., & Page, A. (2007). Application of product differential semantics to quantify purchaser perceptions in housing assessment. *Building and Environment,* 42(7), 2488-2497.

Macomber, B. & Yang, M.C. (2011). The Role of Sketch Finish and Style in User Responses to Early Stage Design Concepts. DETC2010-48714. *Proceedings of the 2011 ASME Intl Design Engineering Technical Conferences*, Aug 28-31, Washington, DC.

Meitner, M.L. (2004). Scenic beauty of river views in the Grand Canyon: relating perceptual judgments to locations. *Landscape Urban Planning*, 68(1), 3-13.

Norman, D. (2005). Emotional Design: why we love (or hate) everyday things. Basic Books, 272 p.

Oh, K. (1994). A perceptual evaluation of computer-based landscape simulations. *Landscape and Urban Planning*, 28(3), 201–216.

Osgood, C.E., Suci, G., & Tannenbaum, P. (1957). The Measurement of Meaning. University of Illinois Press, Urbana, USA.

Pei, E., Campbell, I., & Evans, M. (2011). A Taxonomic Classification of Visual Design Representations Used by Industrial Designers and Engineering Designers. *The Design Journal*, 14(1), 64-91.

Petiot, J.F., & Yannou, B. (2004). Measuring consumer perceptions for a better comprehension, specification and assessment of product semantics. *International Journal of Industrial Ergonomics*, 33(6), 507–525.

Pietsch, S.M. (2000). Computer visualisation in the design control of urban environments: a literature review. *Environment and Planning B: Planning and Design*, 27(4), 521–536.

Radford, A., Woodbury, R., Braithwaite, G., Kirkby, S., Sweeting, R., & Huang, E. (1997). Issues of abstraction, accuracy and realism in large scale computer urban models. In: *Proceedings of the 7th International Conference on Computer-Aided Architectural Design Futures*, Kluwer (*Publisher*), Boston, USA, 679-690.

Rohrmann, B., & Bishop, I. (2002). Subjective responses to computer simulations of urban environments. *Journal of Environmental Psychology*, 22(4), 319-331.

Sheppard, S.R.J. (1989). Visual Simulation: A User's Guide for Architects, Engineers, and Planners. Van Nostrand Reinhold (*Publisher*), New York, USA.

Summers, J., & Shah, J. (2004). Representation in engineering design: a framework for classification. In : *Proceedings of ASME 2005 international design engineering technical conferences and computers and information in engineering conference*, Salt Lake City, USA, Paper No. DTM DETC-2004-57514.

Sutera, J., Yang, M ., & Elsen, C. (2014). The impact of expertise on the capture of sketched intentions : perspectives for remote cooperative design. *Lecture Notes in Computer Science*, 8683, 245-252.

Wergles, N., & Muhar, A. (2009). The role of computer visualization in the communication of urban design—A comparison of viewer responses to visualizations versus on-site visits. *Landscape and Urban Planning*, 91(4), 171–182.

ANNEX 1 – Final list of the 20 bipolar pairs of adjectives (the attributes) constituting " the survey space ", along with the semantic differential scale of Osgood et al. (1957).

	very	somewhat	neutral	somewhat	very	
'A' side	x	x	x	x	x	**'B' side**

'A' side		**'B' side**
contemporary	①	classical
complex	②	simple
hard	③	soft
robust	④	delicate
sharp	⑤	smooth
innovative	⑥	traditional
dynamic	⑦	static
relaxing	⑧	stimulating
quiet	⑨	noisy
varied	⑩	homogeneous
expansive	⑪	compact
discreet	⑫	extravagant
low	⑬	high
composite	⑭	monolithic
modest	⑮	audacious
small	⑯	large
vertical	⑰	horizontal
open	⑱	closed
heavy	⑲	light
common	⑳	unique