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Architrack – Evaluating Architectural Preferences via Eyetracker

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Abstract

Eyetracking of architectural stimuli has a surprisingly short history. *Architrack* used an ISCAN eyetracker to record the visual preferences of architects versus laypeople at their first contact with architectural stimuli, and also to test the influence of urban gestalt factors. Using six *Global Architecture* images, ten seconds of eye movements per image were measured with five professional architects and ten laypeople (5 m, 5 f). Verbal comments were recorded after the eyetracking. Fixation and succession in thematic areas were analyzed frame-by-frame. With high between-stimuli differences, each picture actually was a singular case. Neither the professional focus hypothesis (architects show significantly more fixations on architecture), nor the gender hypothesis could be confirmed. Visual attraction was similar for all subjects at first image contact. Comparing behavioral eyetracker data with verbal data, some gaps were found. Of the urban gestalt factors (Moser) studied with ten color images, "gate," "vegetation" and "vanishing line/point" had explanatory power for both groups.

Introduction

In his antique book on architecture written at the end of the first century B.C., the Roman engineer Marcus Vitruvius Pollio (1908, 2004) developed the art of building from the foundations of taxis (arrangement), diathesis (geometric drawing), eurythmia (appeal of appearance), symmetria, thematismos, and oikonomia (use). Vitruv's eurythmia, also influential for the Renaissance epoch, was the conceptual origin of – as we call it – aesthetics of the built environment.

In environmental psychology, architectural aesthetics was operationalized by verbal descriptions of the onlookers (see Nasar, 1989). On the other hand, human beings have their first spatial experiences and orientation long before the development of verbal abilities. Architecture presents itself as a visual art, and new buildings are objects made to be looked at, and to be liked or disliked. Obviously, this is not all buildings are made for, but exploration, the first contact with architecture, has a visual focus. When human vision comes first, and words later, it would be logical to concentrate on visual behavior and then compare it with verbal behavior. A standard tool for measuring eye movements as visual behavior is the eyetracker (Duchowski, 2003).

Eye movement recording

Visual behavior consists of automatic, unconscious eye movements. They are classified as accommodation, pupil reflex, convergence, nystagms (saccades and pursuit), and fixations. Fixation means an eye-stop for input and processing of visual information. Fixations signal preference. Measurement techniques for nystagms and fixations are electrooculography, coil, electromyography, and infrared reflection oculography called "eyetracker." The latter is a standard method of experimental psychology widely used in clinical, reading, traffic safety, advertising, and software research.

Surprisingly, the eyetracker was only casually applied to architectural stimuli. A cognitive aesthetics approach by Sprinkart (1982) used eyetracker data for works of art, but not for architecture. The earliest record found was a project at Lund, Sweden (Janssens, 1984a, 1984b) with a focus on visual perception and personality factors. Eyetracking was used for design evaluation by Lengyel (1988) and with dementia patients by Kai, Akagi, Oku, and Kusaka (2000). Weber (2004) reported some of his old experiments at IAPS18. A systematic eyetracker application to building evaluation is still missing.

The *Architrack* experiment

Salzburg University has a tradition in environmental psychology. In another project in developmental psychology, the second author was using an ISCAN eyetracker for research on reading behavior of legasthenics (Rayner, 1998), when the third author started her diploma thesis on architectural perception (Frauscher, 2003). The Institute for Local Planning at the Vienna University of Technology, the affiliation of the fourth author, also expressed interest in a test of urban gestalt factors by Friedrich Moser (Moser, Frei, & Voigt, 1988). With four partners, we began the joint project *Architrack* in 2002.

What can behavioral data on eye movements contribute to the understanding of visual exploration of architectural stimuli? As a pilot study, an eyetracker experiment was planned: Contrary to earlier studies, we left out psychological tests and concentrated on the first visual contact with architectural stimuli, as experienced by experts and non-experts, and on behavioral (eyetracker) and verbal data about this process. We did not follow the information content approach of Berlyne (1972), but saw the stimuli as objects with denotations and connotations in a cultural tradition (Boesch, 1991), perceived by different sub-populations with different exploration and interpretation rules (Rambow, 2000).

Method

Subjects

Five male, proficient Salzburg architects were invited as experts. Five male and five female Salzburg subjects with academic education (to counter-balance the experts' training status) were tested as laypeople. The architects were between 41 and 47 years old, and the laypeople between 22 and 51 years (age averages: architects 43.8, lay male 32.6, lay female 31.6 years).

Experimental design

The targets used were six pre-tested scenic color images of newly-built houses from the magazine *Global Architecture* (GA), volumes 68 and 69 (2001, 2002). US and Canadian objects (architects Jackson, Patkau, Goff, Cigolle & Coleman, Shortridge) were used. No human figures were present in the images. The images were projected on a silver screen wall with a video beamer. The subjects, who received no special instruction – "just look at the pictures," – were seated near the ISCAN eyetracker, asked to use a head-rest, and briefed about the non-invasive measuring method.

In a randomized image presentation order, each image was projected for 10 seconds. A calibration picture for the eyetracker function appeared in-between the targets. After the six images, another round of ten images containing urban gestalt factors by Moser selected by the fourth author was presented. Three of the ten images contained human figures. After the eyetracker round, the six GA images were shown again to obtain verbal descriptions of the subjects, which were tape-recorded.

Eyetracker data

The ISCAN eyetracker measured the position of the subject's left eye axis in 20 msec intervals. The US data analysis program produced a) a fixation image with fixation points plus msec duration superimposed on the architectural stimuli, and b) a succession image with numbered fixation points to indicate their sequence. Data were recorded for the six Global Architecture images and for the ten urban gestalt factor images (Moser).

Data analysis

After an initial processing step by the eyetracker data analysis program, the fixation and succession images were analyzed frame-by-frame to obtain statistical data. The architectural images were divided into disjunct thematic areas – façade, landscape, sky, plants, floor, furniture. Relevant variables for further analysis were: Number of fixations (count) per area, fixation durations (singular, cumulative), fixation successions (first contact per area, sequential/repetitive area contacts). Group differences (architects/laypeople, gender) were examined. The subjects' comments on the images were transcribed from the tapes. After a content analysis, the number of words per content category was used for a comparison (triangulation) with the eyetracker data.

Results

Analyzing the data on the pre-tested and carefully selected pictures, it became clear that aggregate data on several stimuli would not make sense, as large thematic differences between stimuli indicated that every picture actually constituted a singular case (Table 1). It was not possible beforehand to find parallel pictures with nearly identical thematic area spaces.

Table 1. Thematic fixation time distribution, all GA images.

% of total fixation time	Male architects	Lay male	Lay female
Façade G1, G2, G6	60.2, 45.2, 8.3	38.5, 39.8, 8.9	46.0, 43.3, 8.8
Landscape G1, G2	27.1, 26.1	11.8, 33.6	14.0, 29.0
Plants G1, G3, G4, G6	3.1, 12.6, 0, 34.6	14.2, 7.5, 0, 21.1	5.8, 11.2, 3.3, 25.6
Furniture G1, G2, G3, G4, G5	4.0, 8.2, 16.2, 35.6, 40.0	28.3, 15.5, 9.1, 59.6, 30.6	13.5, 46.6, 16.9, 45.4, 49.8
Floor G1, G3, G4, G5	21.0, 4.8, 3.5, 14.0	10.0, 26.2, 15.2, 19.3	21.9, 2.3, 7.2, 2.3
Wall G3, G4, G5	18.5, 29.7, 21.0	18.9, 14.4, 28.9	11.3, 20.2, 17.3
Ceiling G3, G4	13.6, 34.3	16.8, 14.4	25.4, 26.1
Glass pane G2, G5, G6	22.1, 28.1, 17.3	18.9, 15.8, 22.3	17.7, 18.1, 10.7
Balcony G5, G6	13.3, 39.8	15.0, 52.2	20.6, 58.8
Dome G4	10.2	6.2	4.9

In a strictly formal approach, it would have made sense to compute the thematic area spaces by planimetry to get correction factors for the fixation values. As practically no two thematic areas had identical texture, color and position in the image, we did not consider such a procedure fruitful.

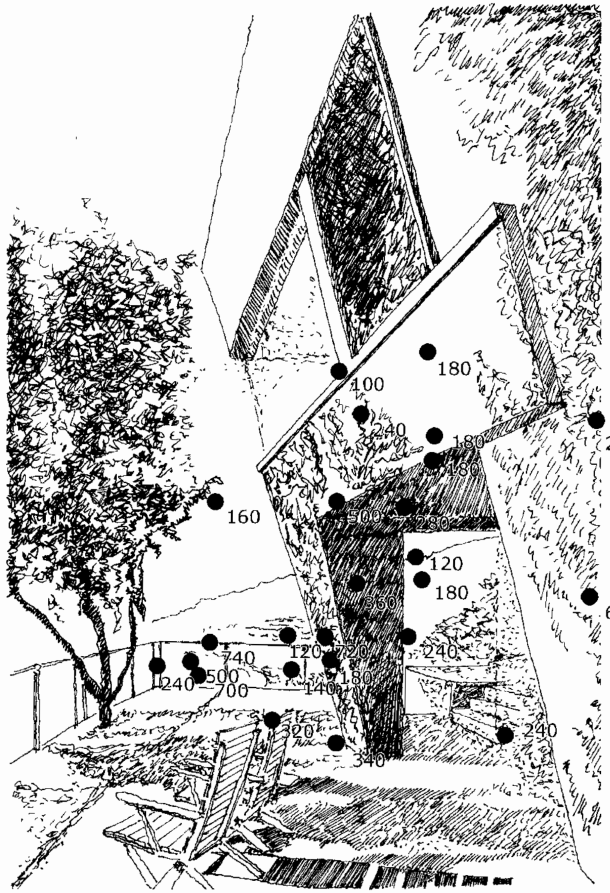
Professional focus and gender hypotheses

Professional focus. It was hypothesized that architects would show significantly more fixations on architecture (façades) because of their professional training and interest. We expected less architecture fixations by laypeople due to thematic distraction by landscape, sky, plants, furniture, etc.

Gender. It was assumed that within the laypeople group and between male experts and female laypeople, significant fixation differences would occur (females: less façade, more plant and furniture attention).

Figure 1 shows fixations of an architect on GA image 1. For 31 thematic areas of the six GA images, only four significant Mann-Whitney U test differences were found between experts and non-experts – for GA 1 and furniture ($U = 4.00$, $z = 1.044$, $p < .05$), for GA 4 and furniture ($U = 5.00$, $z = 2.006$, $p < .05$), for GA 5 and a glass pane ($U = 7.00$, $z = 2.067$, $p < .05$), and for GA 6 and a balcony ($U = 7.00$, $z = 2.205$, $p < .05$). Experts looked shorter at furniture and the balcony, and longer at the glass pane. As the main prediction of a professional focus hypothesis was a difference between expert and laypeople fixations on façades, this hypothesis could not be confirmed.

Figure 1. GA 1 fixations of an architect (B&W drawing of GA photograph by O. Tschuppik).



The Mann-Whitney *U* tests for the gender hypothesis showed no significant differences at all. Therefore, the hypothesis could not be confirmed, either.

Table 2. GA 1 fixation statistics for the experimental groups.

	Male architects	Lay male	Lay female
Mean fixations	23.5	19.2	23.5
Mean duration/fixation	257.7 msec	276.9 msec	172.8 msec
Mean fixations façade	13.0	5.6	9.0
Mean fixations landscape	6.4	3.0	2.8
Mean fixations furniture	1.0	4.4	2.8
Sum duration façade	2168	2000	1760
Sum duration landscape	1908	584	484
Sum duration furniture	200	1320	504

Table 2 illustrates the complexity: Although the mean fixation number is higher for architects and façades, the difference disappears when fixation duration sums are computed. Only the architects' desinterest in furniture, substantiated by the Mann-Whitney *U* tests, is again present for image GA 1.

A succession analysis for images GA 1 and 5 showed no group differences between experts-laypeople. The same general pattern of repetitive contacts and fixation series was present. We conclude that – for the six GA images – no major exploration differences by experts and laypeople were recorded with the eyetracker. Curiosity and visual attraction are similar for all first image contacts.

Triangulation results

Does high visual attraction (behavior), measured via eyetracker, always signal objects of interest that produce more intense (longer) verbal descriptions later?

A case example: GA 1 seen by a male sports student, 34 years (lay) – only 1 façade fixation of 160 msec, 2% of total duration. Verbal comment "… and errr the building itself, that does not say anything to me, too many corners."

GA 1 seen by a pedagogue, 50 years (lay) – 11 façade fixations, 6,180 msec, 62% of total duration. Verbal comment "Well, the architecture interested me very much, because it has edged shapes, very unusual because of its tilt, the house angle is completely different, inclined."

An image-by-image search was made for thematic fixations, their duration and compared with subsequent word counts. Consistent and inconsistent cases were found. Table 3 gives an example for this visual-verbal gap phenomenon in image GA 5 compared to consistent GA 1. However, no group effects were found when triangulating experts-laypeople and gender data.

Compared to an expert-laypeople picture sorting task with verbal descriptions by Bromme and Rambow (see Rambow, 2000), the *Architrack* experiment tested visual behavior first and verbal descriptions later. We have learned several things from the Global Architecture image study:

Table 3. Triangulation results for selected thematic areas and GA 1, 5.

	Sum words	Sum fixations	Total duration msec
GA 1 architects			
Façade	**116**	**114**	**15,840**
Tree	38	3	400
Landscape	36	32	9,540
GA 1 lay female			
Façade	**88**	**45**	**8,800**
Tree	30	7	780
Landscape	53	14	2,420
GA 5 architects			
Gallery	**112**	22	4,540
Window	10	22	5,750
Furniture	23	**39**	**10,100**
GA 5 lay female			
Gallery	**42**	25	4,660
Window	19	15	3,020
Furniture	13	**28**	**4,860**

1. Primary visual attraction and exploration of a new architectural stimulus trigger similar behavior and successions of fixations in experts and laypeople.
2. The "professional focus" of architects on architecture is less pronounced than expected. Only details (furniture) show big group differences.
3. Gender had no effect on the exploration behavior of laypeople.
4. Verbal descriptions follow centers of visual interest, but not always. A visual-verbal gap phenomenon may occur – looking briefly, but speaking longer about it.

Urban gestalt factors (Moser)

The *Architrack* experiment also used ten color images containing urban gestalt factors of Moser, i.e., spatial elements allegedly influencing the visual contact with the environment (Moser, Frei, & Voigt, 1988). The gestalt factors "gate," "building corner," "vegetation," "vanishing line/point," and "eaves edge" were studied. Vegetation has already been identified as a major factor in the environmental aesthetics of townscapes (Nasar, 1989).

Comparing expert and non-expert eyetracking results, it was found that the gestalt factors "gate," "vegetation," and "vanishing line/point" had explanatory power for visual preferences of both studied groups. In percentages of total fixation duration, "vegetation" drew the most attention with 10–100% for experts and 32–97% for laypeople. A "gate" on an image caught 20–73% of expert attention and 10–82% of laypeoples'.

An interesting effect could be studied with the factor "building corner": On an image with low distraction from everyday objects, it took 1–35% fixation time of experts and

15–34% of laypeople. On a second image with high distraction by vegetation and people, fixation time dropped to 0–18% for experts and 0–30% for laypeople.

The Moser gestalt factors, originally illustrated by schematic drawings without urban details such as cars, persons, street lamps, or ads, structured perceptional preferences and were not lost in the abundance of other objects and symbols.

Conclusion

Eyetracking with its behavioral, "objective" data is attractive to planners who show high expectations. Nevertheless, eyetracking is not an easy-to-use "product test," because it needs careful examination of the data stream. Different data sets and aggregation levels (fixation number, duration sum, percent of duration) may point in different directions.

Simple hypotheses (expert focus, gender) were not confirmed in this pilot study. The first explorative behavior seems to be highly similar for different onlookers.

Eyetracking demonstrates gaps between visual attraction and verbal behavior, as is also known from advertising research. Here, the limits of verbal aesthetics research become clear – self-reported behavior is never the same as actual behavior, and verbal reflection may concentrate on minor visual details.

Eyetracking is also a good means of testing planned attention focus on a new building – does it really work at first sight?

The joint study *Architrack* successfully recorded behavioral, involuntary data allowing to check "the eye of the beholder" of architecture parallel to a verbal record. As is already common in other areas of applied psychological research, eyetracking has the potential to enrich our knowledge on the environment-behavior interface of architectural preference.

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