The Role of Expertise in the Perception of Architectural Space

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Abstract — Spatial perception is a fundamental cognitive skill developed lifelong. In architecture, this skill is taken for granted. However, evidence from decades of psycholinguistic research shows that spatial cognition is not universal but depends on factors like native language, gender, or expertise. This interdisciplinary study aims to identify patterns of visual attention characteristic for architects. Results of an eye-tracking experiment provide evidence that architectural expertise influences the distribution of visuospatial attention: In outdoor contexts architects pay more attention to upper parts of buildings; in indoor contexts they pay less attention to people. In both contexts, architects allocate more attention to the spatial layout itself compared with a non-architect control group. We interpret these differences as arising from architects using the grammar of space to decode spatial information. It is desirable for architects to implement the insights from research on spatial cognition when designing spaces, since their own spatial perception differs from that of the users they are designing for.

Introduction

People in Western societies spend about 90 percent of their lifetime in built environments, which implies a constant conscious or unconscious exposure to architecture. The ability to understand spatial configurations is mostly taken for granted by architects as a given constant. Empirical research shows that spatial cognition is not universal but shaped by factors such as language, gender, or expertise (Levinson 2003; Levinson and Wilkins

2006). In general, expertise arises from any human activity that implies a long-lasting occupation resulting in excellent command.

We are interested in understanding how specific expertise guides visual attention, and how the mind manages different, potentially concurring types of expertise. We use eye-tracking (ET) to investigate the visuospatial perception of architectural experts (critical group) compared with nonexperts (control group).

State-of-the-Art

In this section, the most important results from psychological, neurological, and psycholinguistic research on language, gender, and expertise affecting spatial cognition are presented. Speakers tend to rely on the abstract concepts of their mother tongue even when performing tasks that do not require speech (nonlinguistic tasks), showing that linguistic categories are always active and influencing the underlying cognitive processes.

LANGUAGE

All speakers are experts in the language(s) they have grown up with. Monolingual speakers often tend to assume that the conceptual categories of their own language are universal. But languages vary considerably in respect to the spatial categories available in their grammar (fig. 1).

Languages vary in the spatial meanings that their prepositions and verbs encode (Bowerman and Choi 2001). In Korean, the spatial verb *kkita* means "fit together tightly." In English, the preferred expressions are *put + in* or *put + on*. When asked to classify actions such as the ones shown in figure 1a, speakers of Korean will form two groups corresponding to the spatial verbs *kkita* (put into tight containment) and *nehta* (put loosely in or around), while speakers of English will form two different groups, corresponding to the prepositions *in* and *on*. This means that Korean and English native speakers will cognitively process different categories, whenever involved in judgments on shapes and their relation, which is another central concept in architecture.

The grammars of some languages (for example, Korean, Chinese, Japanese, indigenous American languages) contain classifiers, count-words that follow a noun and denote to which category the referent belongs. While English or German lack classifiers, a similar meaning can be found in expressions such as "ten *stem* of roses," or "five *head* of cattle." In languages with classifiers, their use is grammatically encoded, obligatory, such as with numerals. These languages may have several hundred different classifiers. Native speakers classify different nouns that go along with the same classifiers as belonging to the same category.

In an experiment, participants were presented a target object with a specific shape and materiality, and two other objects (one with same shape but

altered materiality, the other with persisting materiality but altered shape) and asked to choose the one corresponding more closely to the target. Speakers of Japanese, for example, showed a strong preference for material over shape, since the material is encoded in the classifier (Lucy 1992). Speakers of languages with no classifiers preferred shape over material (fig. 1b). Such preferences affect speakers' visuospatial perception whenever categorizing relations of shape and materiality, which is a fundamental principle in architecture.

Languages also differ in the frame of reference they employ to localize objects in space. Indo-European languages prefer a relative frame of reference, in which entities are located with respect to the position of the observer: "I left the keys in the right drawer." Even though an absolute frame of reference is also available in these languages, it is not preferred. Other languages by contrast – for example Australian Aboriginal or Mayan languages – are completely lacking the relative frame of reference (and thus do not have words for right or left) but rather locate other entities using the absolute frame of reference: "I left the keys in the northwest drawer." Frames of reference influence subjects even in nonlinguistic tasks: In the "turning tables" experiment (see Levinson et al. 2002) subjects were positioned in front of a table and asked to replicate the specific arrangement of objects seen on the table on another table located behind them. Speakers of languages with a preference for a relative frame of reference place the objects so that orientation was kept unaltered seen from their own point of view. The subject served as point of reference during displacement, although the subject itself was changing orientation, which resulted in an altered order of objects when seen from an absolute point of reference (such as a bird's-eye view). Speakers of languages with a preference for the absolute frame of reference typically placed the objects using exactly the same orientation as seen from the bird's-eye view, even if it meant resorting the objects after having turned around to the target table (fig. 1c).

The reference system is so central to spatial orientation and navigation that it is extremely difficult to just imagine how one's visuospatial perception and speech would need to change if a foreign reference system would need to be applied.

When asked to verbalize a locomotion event (such as a person moving through space), speakers of different languages show specific preferences for mentioning the inferred goal of the movement. The preference depends on whether their language has a grammaticalized aspectual system, such as the option to express ongoingness (English: somebody is walking right now). Observers of languages with a grammaticalized aspectual system are less likely to mention the endpoint of a locomotion event. They can readily express without further examination what is happening at the very moment

of their observation, which results in faster speech onset times (Mertins 2018). Speakers of languages without a grammaticalized aspect (such as German) mention the goal far more often. Due to their grammar lacking a progressive form, German native speakers tend to provide information about a possible goal of the locomotion, interpreting the event as a closed one with a logical end. This results in more delayed speech onset times and more endpoints mentioned (Mertins 2018). ET studies demonstrated that this affects also the allocation of visual perception and increases memory performance for inferred goals (fig. 1d).

Architecture can be seen as the experience of locations connected in space through paths, which implies movement. Locomotion is yet another central element in architecture.
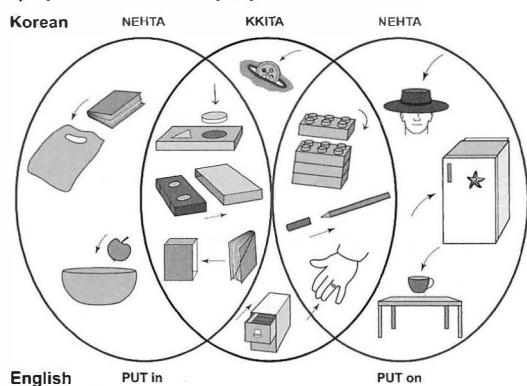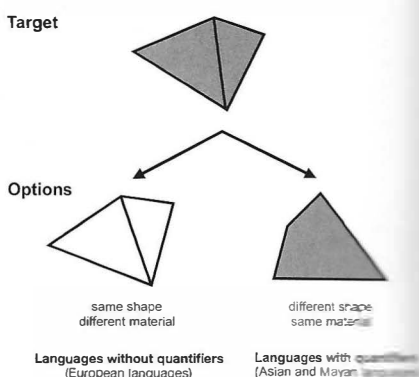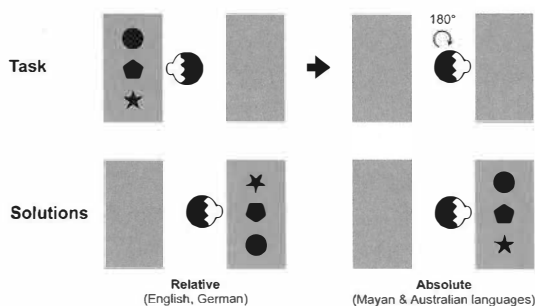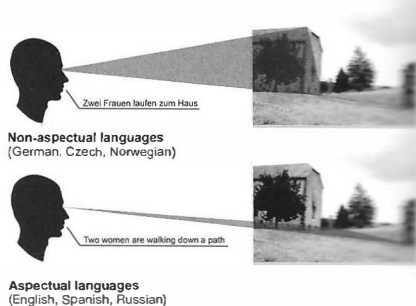

Fig. 1: Examples of experimental tasks for investigating differences in spatial performance

GENDER

In mental rotation tasks participants imagine to rotate a figure and picture how it would look from their perspective after rotation. This is one of the few

tasks in which male participants consistently outperform female participants (Richardson 1994; Quaiser-Pohl et al. 2006). Newer research shows that this gap in performance can be closed by training (Jaušovec and Jaušovec 2012) or disappears when the task has to be performed in a less abstract way, such as by using virtual reality (Parsons et al. 2004). This may indicate that the problem lies with abstraction or training.

In the architectural design process, mental rotation is a fundamental ability and implies change of scale (drawing on paper, imagining in real size). It is adequately important in navigational tasks (such as rotating a topography to foresee situations in wayfinding) and can obviously be altered by training (expertise).

EXPERTISE

Comparing MRIs of taxi-drivers (right-handed males, N = 16) with those of nondrivers, a neuroimaging study (Maguire et al. 2000) showed that profound navigational expertise results in an altered structure of the posterior hippocampus, an area of the brain which stores a spatial representation of the environment. Thus, this area can expand regionally in people with a high dependence on navigational skills.

This study is yet another link into spatial perception in architecture and effects of acquired expertise through training.

Methods

Given the findings presented above, visuospatial perception of architectural space should almost expectedly be affected by expertise. To test the role of architectural expertise in the perception of space, a large-scale ET study was carried out. The method was chosen as the access point since the visual sense plays a key role in architectural perception and eye movements are highly automatized, so that they cannot easily be consciously influenced by participants. The goal was to investigate the visual attention patterns of architects while looking at a scene with architectural content but with no architectural task in focus. Architectural experts (critical group) and a control group (nonexperts) were compared in terms of their visual patterns. Two consecutive sub-experiments were conducted: Experiment A, focusing on outdoor scenes; and Experiment B, investigating indoor scenes.

For the outdoor scenes real-world photos were used, since they are usually characterized by disturbances that are difficult to reproduce in renderings generated via virtual models (signage, dirt, leaves, traffic, etc.). We controlled for the number of such disturbances but did not eliminate them completely, so that the stimuli still appeared realistic. Interior scenes are more readily accepted as realistic even if they show little or no disturbances. We took advantage of this fact to render highly controlled interior stimuli for Experiment B.

Stimuli were presented as still images on a monitor in randomized order (fig. 2). After six seconds a question appeared as text in the lower portion of the image for five seconds. The participants responded orally. Questions were related to the image but not directly connected to the research interest and responses were not analyzed. The question was there to give participants an explicit task and keep their attention high. Fillers were used, doubling the critical stimuli in number and showing nonarchitectural content.

Experimental Procedure
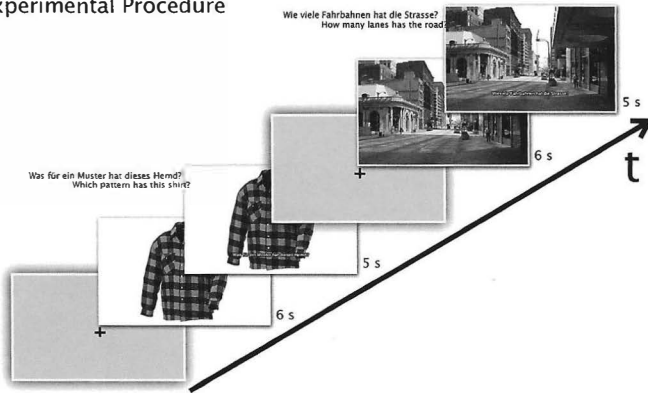
Critical Stimuli A (outside)

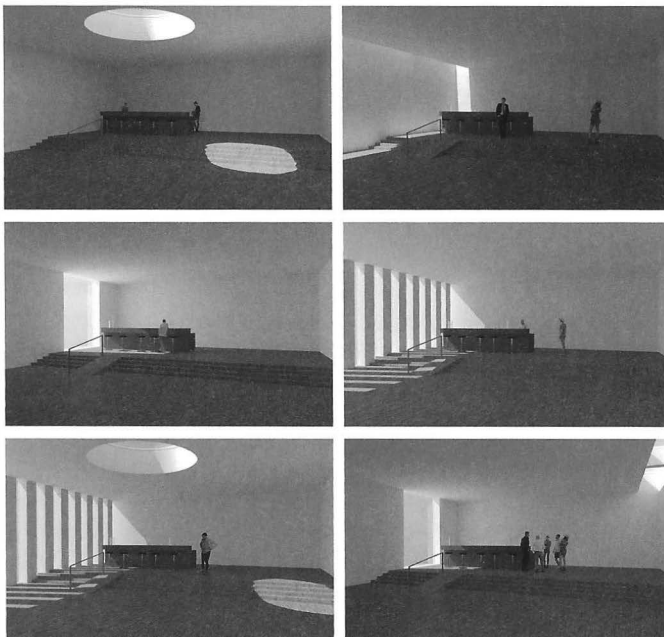
Critical Stimuli B (inside)

Fig. 2: Experimental design, including examples of critical stimuli for experiments A and B

The participants' gaze positions were recorded for the first six seconds before the appearance of the question, using an SMI RED500 eye-tracker under laboratory conditions and then analyzed. All participants were native speakers of German, and the experiment was conducted in German. The experts were architects or graduate students of architecture. The control group consisted of age-matched graduate students of humanities with no expertise in architecture or related spatial skills such as arts, photography, modeling, gaming, or sports (controlled by questionnaire).

EXPERIMENT A: EXTERIOR (N = 96)
The critical stimuli were five photographs depicting built environments (urban scenes). The critical group comprised 48 experts and 48 nonexperts, both balanced for gender.

EXPERIMENT B: INTERIOR (N = 64)
The interior stimuli were six daylight pictures rendered from digital models using natural lighting parameters and raytracing. They were derived from a common spatial geometry (box shape) shown from an identical camera position. Natural light was let in either via openings in the walls, through the ceiling, or a combination of both with two geometries per condition. The scenes included presenting different numbers of humans in alternating positions around a bar counter. The critical group consisted of 19 experts and 45 controls with mixed gender.

Results
The ET data was analyzed using the SMI software BeGaze, and the amount of visual attention both groups dedicated to the predefined areas of interest then compared (dwell times in ms). The statistical data analysis and examples for the areas of interest for both experiments are presented in figure 3.
The statistical analysis showed that for the outside scenes, architects dedicated more attention to the upper area of the stimuli, while nonarchitects looked longer at the lower portion of the scene (pedestrian level). The results of the inside scenes showed that nonarchitects looked significantly longer at people and furniture than architects. Additionally, for the outside contexts, there was a gender effect within the expert group. This difference was not confirmed for the inside scenes.

Discussion
The results demonstrate that experts allocate their attention differently from nonexperts when looking at outdoor and indoor spaces. Even though the mixed-gender architects performed differently to the group of laypersons, gender differences inside the expert group were also giving hints to a possible sublevel of expertise.
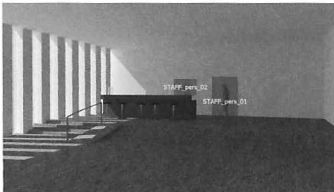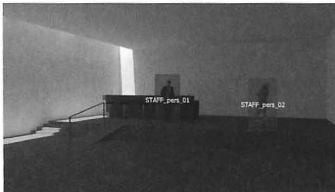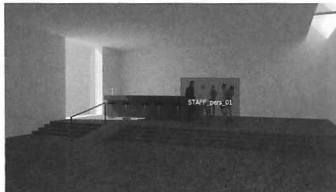
OUTSIDE Stimuli (N = 5)		Dwell time (ms)		Statistical test			Effect size	
Comparison	Group	average	SD	t-value	p-value	DF	Cohen's d	Size
experts vs. non–experts	architects	2487	1193	359.27	0.00017	478	0.60	medium
	control	1778	1155					
male experts vs. female experts	male	2685	1194	198.99	0.024	233	0.54	medium
	female	2065	1103					

INSIDE Stimuli (N = 6)		Dwell time (ms)		Statistical test			Effect size	
Comparison	Group	average	SD	t-value	p-value	DF	Cohen's d	Size
experts vs. non–experts	architects	1352	875	2.05	0.0203	190	0.51	medium
	control	1881	1191					
male experts vs. female experts	male	1033	744	0.16	0.87	86	not significant	
	female	1080	722					

Fig 3: Results of the statistical analysis based on dwell times on areas of interest
Interior people: Male 13, Female 75

While looking at the interior spaces, nonexperts were mostly interested in the human occupation or potential use of the space (exterior: pedestrian level, interior: people) while architects spent less time paying attention to these elements. This enables experts to dedicate more attention to the architectural space housing the human scene. These patterns mirror the architects' professional occupation with connecting spatial layouts to possible uses. We interpret these findings as evidence that architects are structuring the architectural space following the grammar of space (Mertins et al. 2017), which is in this case developed through professional expertise, specifically concerning elements such as the geometrical layout of the urban space, information about the cubature of a structure, zoning and articulation of facades, building style, and architectural detailing, but also the lighting situation and conditions. The latter two are especially important when structuring interior spaces. Cognitive and visual attention has limits: focusing on one element necessarily implies not paying attention to others. Individuals manage

this distribution of attention unconsciously in line with their expertise. Attention seems to be in interaction with and driven by expertise. The different variables affecting the allocation of attention (native language, expertise, gender) have to be somehow balanced and managed by the brain in order to decide to which elements in the visual field how much attention in real time is spent to, which explains the different strengths of the effects found between various groups. Until now, not much is known about how exactly these different factors are weighed against each other. More research is needed to clarify this process.

Conclusions and Consequences for Architects

In line with previous research we argue that general spatial cognition is not universal and expertise in architecture based on the grammar of space is one of the most relevant factors guiding the perception of architectural space. These findings are of great importance for applied architecture: For exterior and interior spaces the perspective of experts differs profoundly from the perspective of nonexperts. This has immediate consequences for the way architectural design should be thought through and executed: not as a top-down process implemented from the viewpoint of the experts (planners) but far more as a bottom-up process executed by experts through the eyes of the target group – the nonexperts (users).

Stated this: How can architects evaluate the architectural means deployed in their designs if they lack knowledge about how these actually perform with nonexpert users? Empirical research has the potential to advance these questions beyond personal taste and fashions into a more scientifically based understanding of spatial design. This is not to imply losing creativity in the design process but would make the process less arbitrary, more justified, and more targeted. Empirical research on architectural design has as yet been underused as a tool by architects. It has the potential, if empirical testing of architectural designs can be integrated into the field, to bring about more objective and user-friendly results.

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