Exploring isovist-based correlates
of spatial behavior and experience

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Abstract

Isovist and visibility graphs offer the great chance to describe spatial properties of environments generically. This paper discusses theoretical and methodological issues arising from the practical application of isovist analysis for empirical research in the field of spatial cognition and architectural psychology. The background of two experiments exploring the influence of spatial form and structure on behavior and experience is presented. Since isovists and visibility graphs allow the translation of a wide range of spatial environments into a common and generic data format, a central analytical step is the derivation of specific characteristic values. As most descriptors mentioned in the literature are rather basic and derived from formal analysis, their descriptive relevance for human spatial perception, behavior, and experience cannot be taken for granted. Hence, the derivation of meaningful descriptors was done theory-driven and empirically verified particularly focusing on classic theories of environmental psychology. Furthermore, strategies for solving the practical issue of finding a suitable scope of application for the analysis as well as the relation between the measurands are discussed. Based on this, a preliminary minimal set of isovist derivatives generically capturing behaviorally and experientially relevant properties of architectural space is proposed.

Introduction

Form and configuration of architectural space influence experience and behavior. When, for example, people enter an empty restaurant, they do not sit down at an arbitrary place, but carefully choose a seat in relation to the surrounding architectural features (Robson, 2002). Likewise, when looking for specific places in unfamiliar environments, movement decisions during exploration contain regular patterns that are probably induced by the shape and configuration of the spatial environment and by the visuo-spatial characteristics of decision points. Also several theories from environmental psychology such as "prospect and refuge" or "defensible space" explain human behavior and experience as dependent from certain formal properties of the environment.

While the truth of the initial statement is therefore beyond dispute, few theories and empirical studies have aimed at analyzing the corresponding interrelations comprehensively,
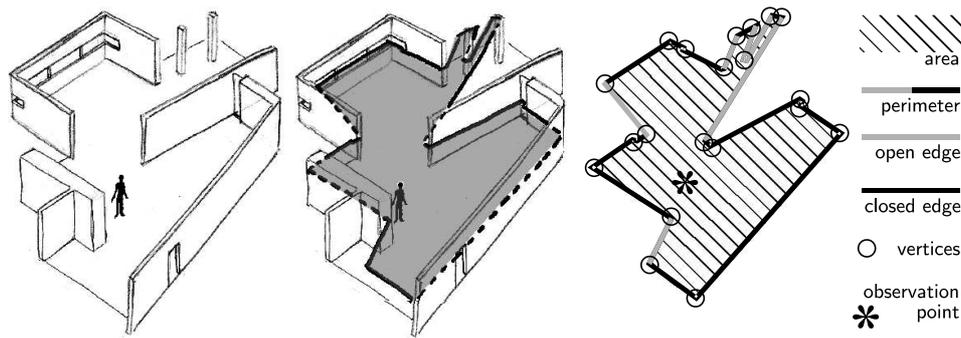
Figure 1: Generating isovists: Left: a hypothetical indoor environment; middle: the gray area is visible from the person's observation point within the environment; right: the resulting isovist and its basic measurands.

but have rather made use of qualitative descriptions of certain selected spatial situations. Therefore, they are often difficult to integrate and do not provide a basis for systematic spatial analysis. One methodological difficulty empirical studies have been faced with is the issue of comparability between arbitrarily shaped environments. For large-scale spatial configurations such as city quarters, the techniques of classic space syntax (Hillier & Hanson, 1984; Hillier, 1996) allow the translation of spatial layouts into mathematical graph representations that offer a basis for quantitative descriptors. At the scale of single spaces or small-scale spatial configurations, isovists (Benedikt, 1979) and related techniques such as visibility graphs (Turner, Doxa, O'Sullivan, & Penn, 2001) have turned out to be a promising means to describe properties of architectural space generically.

In the following, theoretical and methodological issues arising from the practical application of isovist analysis for empirical research are discussed. (a.) While the mathematical combination of basic isovist measurands allows for a vast number of spatial descriptors, their relevance for human behavior can not be taken for granted a priori. The derivation of meaningful isovist measurands is therefore done theory-driven, by revisiting classic theories from environmental psychology. (b.) Two recent empirical studies are reviewed that tested the behavioral relevance of the selected isovist measurands. (c.) Strategies for solving the practical issue of finding a suitable reference frame and scope for the application of the analysis as well as the relation between the measurands are discussed. (d.) Finally, a preliminary minimal set of isovist derivatives generically capturing behaviorally and experientially relevant properties of architectural space is proposed.

Isovist and visibility graph analysis. For analyzing spatial characteristics of small-scale environments, Benedikt (1979) has proposed *isovists* as objectively determinable basic elements. Isovists are viewshed polygons that capture spatial properties by describing the visible area from a single observation point. From these polygons, several quantitative descriptors can be derived that reflect local physical properties of the corresponding space such as area, perimeter length, number of vertices, length of open or closed boundaries (see Figure 1). These basic measurands can be combined to generate further integrated values. For example, the quotient of area and squared perimeter can be conceived as the isovist polygon's roundness ratio.

In order to better describe the spatial characteristics of an environment beyond a particular observation point, Turner et al. (2001) have developed *visibility graph analysis* that

integratively considers multiple positions within an environment by computing the inter-visibility of positions regularly distributed over the whole environment. This technique offers further second-order measurands like for example on visual stability (e.g., clustering coefficient) and, similar to original space syntax, global characteristic values such as integration (mean shortest path length). A further advantage of visibility graph analysis is its strict bottom-up approach, hence, it can be generically applied and the analysis process has the potential to be widely automated.

While explicitly related to Gibson's (1979) theory of ecological visual perception, the behavioral relevance of isovists and visibility graphs was not backed initially by psychophysical empirical findings. However, isovists describe spatial properties from an inside beholder-centered perspective, and meanwhile there is first empirical evidence that they indeed capture environmental properties of space that are relevant for spatial behavior and experience. For example, case studies on spatial behavior in the Tate Gallery (Turner & Penn, 1999) have revealed high correlations between visibility graph measurands and the statistical dispersal of visitors. Readinger (2002) has found indications for the relevance of isovists for the perception of object configurations.

The derivation of isovist measurands from qualitative theories

Overview

This section gives an overview on the translation of existing qualitative theories of environmental psychology and normative knowledge on affective qualities of architectural space into quantitatively testable hypotheses. This operationalization was done in a two-step approach. First, existing qualitative theories were collected, tentatively analyzed on their underlying spatial properties, and summarized. When appropriate, these assumed basic spatial properties were then related to existing isovist and visibility graph measurands from the space syntax literature (mainly Turner et al., 2001). Likewise, formal measurands described in earlier approaches of empirical aesthetics were applied (e.g., Berlyne, 1972). Furthermore, several additional characteristic values were created by combining basic measurands mathematically in order to capture specific aspects described in theories.

Theories on spatial qualities

Already basic adjectives describing spatial size have a strong emotional connotation (e.g. narrow, cramped, poky, spacious, ample). Analogously, architectural theory (e.g., Joedicke, 1985) suggests that the most basic quality of architectural space, its *spaciousness*, is an important constituent of its experience. The pathological extremes of agoraphobia and claustrophobia demonstrate that direct emotional responses to the dimension of space can be very intensive. Also ecological action theory (Kaminski, 1976, pp. 255-259) makes direct affective responses to spaciousness probable, because the size of a space widely determines the range of possible or preferred functions. Additionally, the theory of proxemics (Hall, 1966) suggests a different weighting of space according to its distance from the observer. So, in sum, measurands describing the mere size of available space, possibly moderated by egocentric distance, appear to capture relevant qualities of architectural space.

Related to the basic spaciousness quality, the theories of "prospect and refuge" and "defensible space" suggest preference patterns for certain configurations combining enclosure and conversely *openness*. For example, Appleton (1988) proposed that, due to their evolution in the savannah, humans prefer environments that offer various cover and at the same time allow overlooking other spaces. From the defensible space theory (Newman, 1996) it can be derived that prospects ideally extend in only one direction, hence, asymmetries in the opening distribution might be important.

A further group of theories relate to perception and information processing. Environments widely differ with regard to their structuring, perceptibility, and the ease of encoding them into spatial memory. Several authors have suggested that environmental properties determining the respective structural properties also affect the emotional experience (e.g., Berlyne, 1972; Kaplan, 1988; Nasar, 1988; Lozano, 1988; Stamps, 2002). For describing the underlying factors, a bunch of collative concepts and terms such as complexity, diversity, visual entropy, perceptual richness, order, legibility, clarity, and coherence has been used. All in all, there are strong indications for at least two main dimensions, that may be provisionally termed *complexity* (implicating diversity, entropy, richness) and *order* (comprising also legibility, clarity, coherence). While architectural theory tends to stress the aesthetic value of the latter (e.g., Weber, 1995), psychological experiments have rather concentrated on effects of complexity. So, taken together, the theories suggest that both complexity and order are important basic structural qualities of architecture .

Closely related to these static collative stimulus properties are concepts that relate to the *predictability* of an environment (e.g., Mehrabian & Russell's "novelty" and "uncertainty" as part of information rate, 1974, pp. 75-97). Also the "mystery" theory (Kaplan, 1988) suggests behavioral and emotional responses by environments promising new information when moving further. The translation of predictability into formal descriptors seems however difficult, since its effectiveness may strongly depend on non physical factors such as previous exposure and familiarity. Yet at least aspects of predictability may be related to similar physical properties as the openness quality.

Translation of spatial qualities into isovist measurands

In a second step, these four basic spatial qualities spaciousness, openness, complexity, and order were tentatively translated into isovist measurands. Table 1 gives an overview on these hypothesized connections and on the calculation methods of selected measurands.

The basic *spaciousness* quality was expected to be easily approximated by basic measurands such as mere isovist area (also called neighborhood size), the area of the the convex part of the isovist, or its free near and medium space. Since convex partition is mathematically non-trivial and often ambiguous, it was decided to test for an additional influence of distance by partitioning the visibility graph into multiple depth segments and calculating the proportion between actually and theoretically visible graph nodes at the given distances (measurands free near/medium space).

The second quality *openness*, motivated by prospect and refuge, defensible space, and predictability theories, was seen to relate to two different physical aspects, the number of vistas into adjacent rooms and the rate of physical enclosure. The former could be probably

basic spatial quality	isovist and visibility graph based descriptor variables	calculation method
spaciousness	isovist area	neighborhood size
	free near (medium) space	n visible graph vertices at 2 (4) m distance
openness	isovist openness	$\text{length}_{\text{open edges}} / \text{length}_{\text{closed edges}}$
	jaggedness	$\text{isovist perimeter}^2/\text{area}$
	revelation	(Σ area adjacent isovists - isovist area) / isovist area
complexity	number of vertices	n isovist vertices, n segments
	vertex density	n vertices / area
	roundness	$\text{isovist area}/\text{perimeter}^2$
	jaggedness	$\text{isovist perimeter}^2/\text{area}$
	clustering coefficient	n intervisibilities within current neighborhood / (neighborhood size*(neighborhood size -1))
order	symmetry	n symmetry axes
	redundancy	$n_{\text{segments}} / n_{\text{unique segments}} +1$

Table 1: Summary of the hypothesized relations between basic spatial qualities and isovist measurands.

captured by measurands describing the convexity of isovists such as clustering coefficient and jaggedness, the latter simply by the openness ratio. Furthermore, a more behaviorally oriented measurand was designed called revelation coefficient that was calculated on the visibility graph as the relative difference between the current and the adjacent isovist areas. Similar to the clustering coefficient, a high revelation coefficient indicates an area of low visual stability and potential information gain by moving further. Revelation might be especially relevant when actively navigating. In order to facilitate a distinction between openness-related measurands and spaciousness, all these measurands were basically scale invariant.

The third group of factors summarized in the concept of *complexity* was expected to denote either the absolute amount of information or features, or the relative information density. Reasonable approximations for measuring complexity could therefore be the number of vertices or segments making up the current isovist, vertex density, and again clustering coefficient, or the isovist jaggedness. Similar measurands have been successfully used by Berlyne (1972) to describe pure polygons and by Stamps (2000, pp. 39-43) for building silhouettes. Although derived from a quite different theoretical background, an overlap with measurands capturing openness became apparent.

Finally, normative architectural theory (Ching, 1996) suggested to approximate properties contributing to visual *order* by looking for redundancy patterns within the isovists, such as symmetries or absolute and relative number of unique polygon sections. Since none of the existing measurands from the isovist literature related to such kind of factors, several mathematical combinations of the basic measurands were generated. For an empirical validation of their hypothesized relation to visual order, eight participants sorted printed cards showing 16 isovist polygon contours (cf. Figure 2) according to the criterion of regularity. The subsequent analysis showed a large consistency within the rankings. Two structural main factors became apparent: The average ranking could be described almost perfectly (correlation coefficient r=0.94, p<.001) by the formula:

$$polygon\ regularity = -\frac{n_{unique\ polygon\ sections}}{n_{symmetry\ axes} + 1}$$
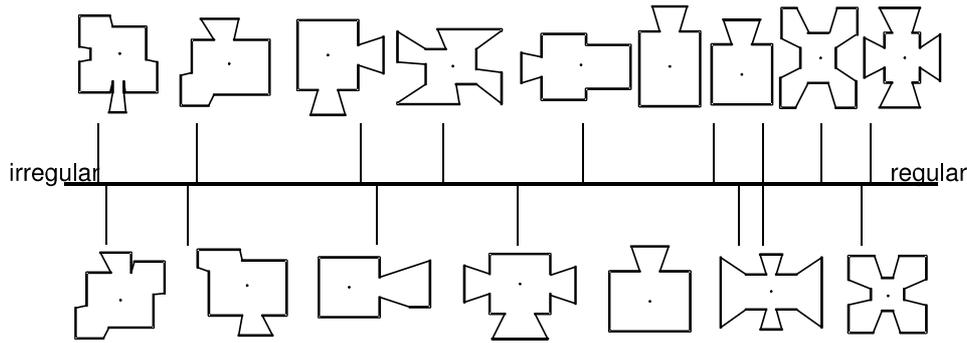
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Figure 2: Averaged result of the regularity ranking of isovist polygons by eight participants.

Methodologically, the automatic detection of the underlying properties appeared to be difficult, partially due to issues of mathematical accuracy, partially due to the unclear relevance of imperfections, suggesting the notion of partial symmetries. Therefore, for the following exploratory empirical studies the regularity factors were evaluated manually for each scene at only a single reference point.

Empirical studies

This section gives a brief overview on the procedure and main outcomes of two recent experiments that applied isovist analysis in an architectural psychology and spatial cognition context. Experiment 1 quantitatively tested the theoretic framework and the measurands developed in the previous section on their predictive power for affective responses to architectural space. For a detailed description of the method and results, please refer to Franz, von der Heyde, & Bülthoff (2005). Experiment 2 tested the perceptibility of isovists and the predictive power of the derivatives for performance in a navigation task. It is presented in more detail in Wiener & Franz (2004).

Experiment 1 - predicting experiential qualities of architecture by its spatial properties

Introduction. While experiential qualities of rectangular architectural spaces can be effectively predicted from their proportions and area (Franz, von der Heyde, & Bülthoff, 2003), these factors obviously cannot be directly transfered on open-plan indoor spaces. In this experiment, the suitability of isovist and visibility graph derivatives for capturing emotion-affecting properties of arbitrarily shaped architectural spaces was tested.

Background. A central constituent of the experience of architecture are affective responses. Russell (1988) defines affective qualities as the prevalent mood-altering capacity of architectural environments. The theoretical framework of Mehrabian & Russell (1974) describes emotion by only three basic underlying dimensions (pleasure, arousal, and dominance). Emotional responses can be approximately quantified using verbal scaling techniques (affective appraisals). Furthermore, several studies (cf. Stamps, 2000, pp. 114-138) have

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Category	English low extreme	English high extreme	German low extreme	German high extreme
interestingness	boring	interesting	langweilig	interessant
pleasingness	unpleasant	pleasant	unangenehm	angenehm
beauty	ugly	beautiful	hässlich	schön
spaciousness	narrow	spacious	eng	weit
enclosure	open	enclosed	offen	geschlossen
complexity	simple	complex	einfach	komplex
clarity	unclear	clear	unübersichtlich	übersichtlich

Table 2: English translations and original terms of the rating categories used in the semantic differential. The experiments were conducted in German language.
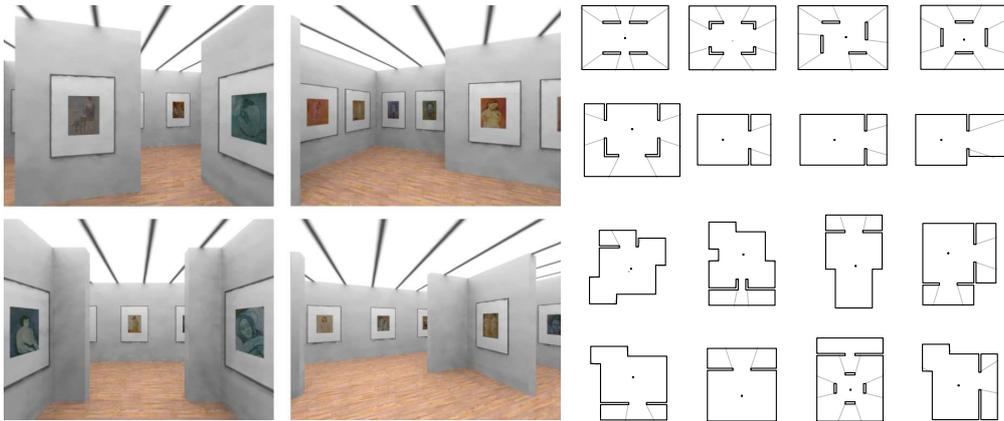

Figure 3: Left: Example screenshots of the virtual gallery rooms. Right: the isovists of the central observation points overlayed on the floor plans.

convincingly demonstrated that averaged appraisals indicate meaningful and stable main trends offering a basis for generalizable predications.

Method. Based on the previously introduced theories, specific hypotheses on relations between isovist properties and affective responses were raised, and additional measurands designed. Altogether, 33 local characteristic values derived from the isovists were calculated for one central position in each of 16 fictive gallery spaces (cf. Figure 3). In an psychological experiment, the experiential qualities of each scene were rated by 8 participants using a semantic differential comprising 6 primary dimensions of architectural experience (cf. Table 2). The rooms were presented as radiosity-rendered 360° panorama images on a 130°x90° wide-angle virtual reality system. The exploratory analysis tested for correlations between the averaged affective appraisals and the isovist-based scene descriptors that were calculated using a custom made spatial analysis tool (see `http://www.kyb.mpg.de/~gf/anavis`).

Results. Significant correlations to measurands capturing all four basic spatial qualities were found. The differences in the affective appraisals between the scenes could be best explained statistically by the factors vertex density and number of symmetry axes for pleasingness (explained proportion of variance R^2=.69), by isovist area, free near space, the number of symmetry axes and vertices for beauty (R^2=.78), and by isovist roundness, openness ratio, vertex number and density for interestingness (R^2=.73). Regarding the rating dimen-

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sions that directly relate to the basic spatial qualities, rated spaciousness was significantly correlated with both isovist area and free near space (R^2=.78), and the analysis of rated complexity found as regressors number and density of isovist vertices, number of unique polygon sections, roundness and openness ratio (R^2=.93).

Interpretation. Altogether, the study strongly suggested that qualitative theories can be translated into isovist and visibility graph measurands that generically capture spatial properties affecting the experience of architecture.

Experiment 2: A comparison between spatial behavior and spatial form

Introduction. Spatial properties of architecture influence human navigation behavior. Empirical support for this statement comes from several studies that investigated the influence of selected features of space on human navigation behavior. For example, O'Neill (1992) demonstrated that wayfinding performance decreased with increasing floor plan complexity. Werner & Long (2003) have shown that the misalignment of local reference systems impairs the user's ability to learn the layout of an environment. Janzen, Herrmann, Katz, & Schweizer (2000) investigated the influence of oblique angled intersections within an environment on wayfinding performance. Wiener & Mallot (2003) have revealed an influence of environmental regions on human navigation and route planning behavior.

The studies mentioned above relied on qualitative descriptions of selected features of space, which makes them difficult to compare. In order to study interrelations between properties of space and spatial behavior systematically, it is necessary to relate spatial behavior to generic descriptions of space. The experiment described here studied the suitability of isovist derived measurands for this purpose. Isovist-based descriptions of 16 environments were correlated with behavioral data from active navigation tasks. Particular interest concerned whether isovist measurands a suitable means to predict spatial behavior and whether subjects were able to perceive basic isovist measurands such as isovist area.

Method. Using a desktop virtual reality setup with a simulated field of view of 90° x 73°, subjects were placed in the same virtual indoor scenes as in Experiment 1 (see Figure 3). They actively navigated through the environments in the ego-perspective using a joypad. In each of the sixteen indoor scenes, subjects were asked to navigate to the positions that maximized the visible area (isovist area) and to the position that minimized the visible area. For each indoor scene navigation performance was evaluated by comparing the isovist area at the chosen positions with the isovist area at the positions with the actual highest or lowest values. Additionally, subjects performance was correlated to global isovist descriptions of the corresponding environments.

Results. Overall, subjects showed very good performance for both navigation tasks (finding smallest isovist: P=.93 ±; finding largest isovist P=.90 ±, t-test: t=.96, df = 29.97, p=.3), demonstrating that they could perceive the area of isovists very well. Furthermore, subjects' performance in finding the positions that maximized and minimized the visible area for the 16 indoor scenes strongly correlated with the isovist measurands jaggedness, clustering coefficient, openness, and revelation while performance did not significantly correlate with the measures for neighborhood size and the number of vertices (see Figure 4).
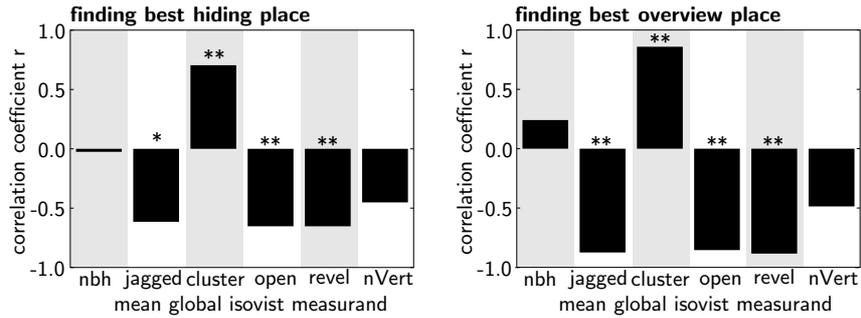
Figure 4: Correlation between subjects' navigation performance and the isovist measurands neighborhood size (**nbh**), jaggedness (**jagged**), clustering coefficient (**cluster**), openness (**open**), revelation coefficient (**revel**) , and number of polygon vertices (**nVert**).

Interpretation. The results of this study provide further support for the notion that isovist and visibility graph measurands capture behaviorally relevant properties of space that allow to predict spatial behavior for the chosen navigation tasks. Furthermore, the high level of performance in both experimental tasks demonstrates that humans can perceive the basic spatial quality spaciousness very well.

Discussion

Global and local references for isovist analysis

In Experiment 1, subjects' affective responses were correlated to local isovist and visibility graph measurands that were obtained from a single central position within the environment. In Experiment 2, subjects' navigation performance was correlated to global measurands that were obtained by averaging over isovist measurands derived from multiple positions. This methodological difference followed the design of the experiments: As subjects experienced the environments from a static position in Experiment 1, a local approach describing spatial properties of the environments from a single corresponding position seemed reasonable. On the other hand, in Experiment 2 subjects were allowed to freely navigate through an environment. Therefore, a global approach describing the environment as a whole was seen as more appropriate.

Problem statement. This pragmatic distinction, however, provoked for a more general examination. In contrast to Experiment 1, humans almost never experience spatial situations from a single position only. Rather, in real life a spatial situation is approached and explored before affective appraisals are given. A local approach would raise the question of how to select the location from which the isovist and visibility graph measures describing the spatial situation are obtained. This issue will be discussed in more detail below, and possible strategies for selecting adequate locations are compared. Simple global strategies also have their limitations and methodological drawbacks. While the virtual indoor scenes of Experiment 1 and Experiment 2 were relatively small and completely closed, in real life humans often face large urban spaces or complex and only vaguely delimited architectural indoor spaces consisting of multiple interconnected subspaces. In such environments,

global approaches that simply average their basic measurands over the whole area will describe the environment at a scale level that is inappropriate for most spatial behavior. In this case it is therefore necessary to partition large environments into smaller subspaces before calculating averaged measurands. However, this raises the well-known problem of defining reasonable rules for space partitioning that are generically applicable. Another issue concerning global strategies is the question of how to summarize the global isovist measures. In Experiment 2 local isovist measurands were simply averaged over the entire environments. This method, however, widely ignores the distribution of the underlying data and all positions within the environment are treated as being equally important. It is questionable whether this simple approach leads to optimal results.

Strategies for selecting local reference points. One possible strategy is to select the *spatial center* of the environment. While no unique definition can be given for the center of an environment, humans mark the center of spatial environments on floor plans remarkably consistent. The results of a small preliminary study can be interpreted such that all 16 participants chose as overall center either a position near to the centroid of the entire environment, the geometrical center of the largest embedded subspace, or they integrated between these two extremes (see Figure 5). In Experiment 1, the strategy of selecting the center of the largest subspace was followed.

An alternative more formal strategy that is generically applicable is the selection of reference points according to some visibility graph criteria. For example, a very straightforward strategy could be to choose the position that maximizes the isovist area (*isovist area maxima*). These positions allow for the best overview and might therefore represent the entire environment best. Figure 5 displays the position that maximized the visible area for the virtual indoor scenes of Experiment 1 and Experiment 2 as small crosses.

Statistical comparison. In order to compare the two local approaches, for both reference points isovist measurands were calculated in each of the 16 virtual indoor scenes and analyzed for correlations. Although the reference points resulting from the two local strategies were clearly different in all of the environments (cf. Figure 5), very strong and significant intercorrelations between the corresponding isovist measurands were found ($r > .70$, $p < .01$, cf. Figure 6 left). Additionally, both local approaches were correlated to the global approach used in Experiment 2 (see Figure 6 middle and right). Here the global isovist measurands were obtained by averaging local measurands calculated on a 50 cm grid covering the entire environment. Again, the level of intercorrelations between the approaches was surprisingly high ($r > .67$, $p < .01$).

Implications. The results of the statistical comparison implicate that in the reported behavioral experiments all three approaches would have explained a similar proportion of overall variance. In other words, the general outcomes appeared to be remarkably robust with respect to the selection of a strategy for the derivation of scene descriptors. Hence, if an experimental question requires to consider local spatial properties, the results suggest that already measurands obtained from single positions could have significant predictive power. Additionally, the apparent robustness of the results against moderate deviations from optimal local reference points opens up the use of formal selection criteria that only partially correspond to manual selection. Vice versa, if no suitable formal criterion can be found, the manual selection of reference points can be justified, also by the high level of communality between judges.
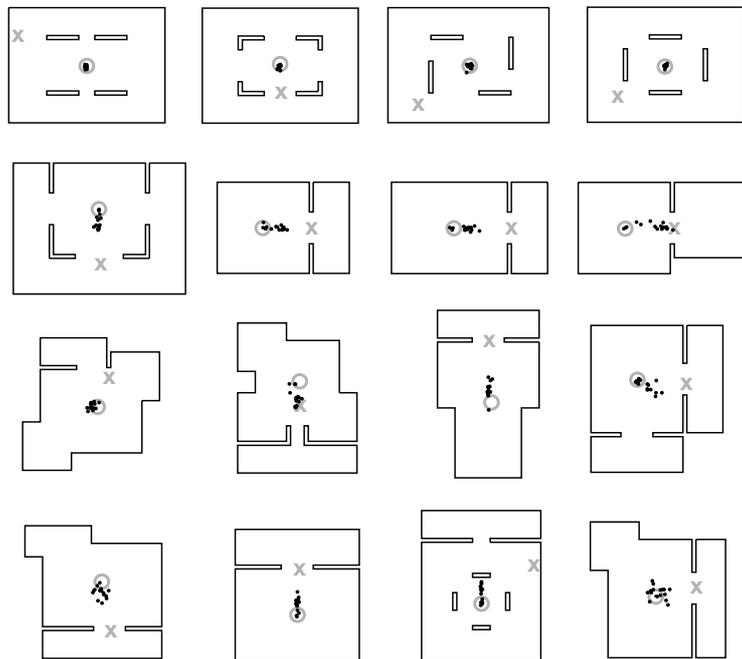
Figure 5: Two different strategies for selecting local reference points for isovist analysis The central position of the largest subspace is marked by a circle, the position that maximized the visible area is marked by an x; responses of 16 subjects (8 female, 8 male) that were asked to mark the central position in each of the 16 environments are shown as dots.
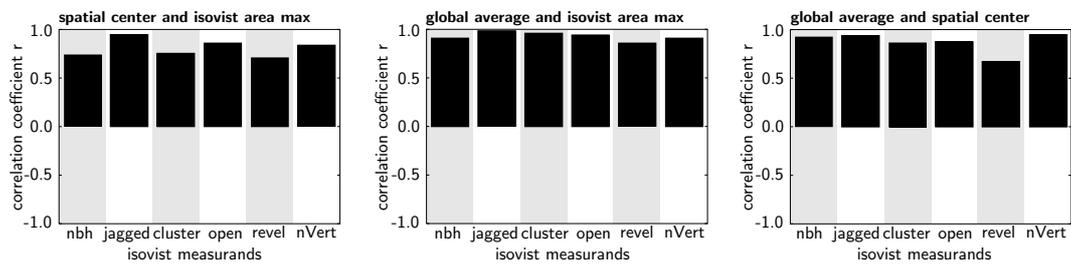

Figure 6: Left: Correlations between isovist measurands obtained from two local reference points. Middle and right: Correlations between the local measurands and corresponding averaged global measurands as applied in Experiment 2.

Relations between isovist measurands

As apparent from Figure 4, a very similar pattern of correlations was found in Experiment 2 for the isovist measurands jaggedness, clustering coefficient, openness ratio, and revelation coefficient. Analogously, a high level of intercorrelations between these measurands was found, even when calculated over the whole environments ($r^2 > .81$, p<.001). While this finding cannot be expected from the completely different mathematical bases of the measurands (cf. Table 1), it can be well explained by the underlying theoretical assumptions. All four measurands are related to the basic openness quality, which apparently was equally well rendered by all of them. Due to this theoretical explanation, it seems likely that the strong intercorrelations are more than an artifact of the small scene sample size.

Additionally, several significant correlations between mathematically scale-independent variables and isovist area were found (e.g., correlations isovist area with number of symmetry axes and jaggedness both r=-.61, p<.05). While not directly explicable from the theoretical framework, also this result appears to be more than just a coincidence: Architectural forms are not scale-independent, but substantially determined by the absolute human scale. Since spatial features below a certain extent would be behaviorally irrelevant for humans, one can expect them to be found depending on the room size.

Altogether, the two experiments covering both spatial behavior and experience found empirical evidence for factors from all assumed underlying spatial qualities. Due to the high level of intercorrelations, additional differentiations did not allow many further observations. While generalizations on basis of two exploratory studies are of course highly speculative, one could nevertheless summarize that already a small number of locally raised isovist measurands would have explained a similarly large proportion of the observed behavioral variance. For example, a set consisting of isovist area, jaggedness, openness ratio, and the number of vertices and symmetries appears to be promising selection that only consists of direct isovist derivatives.

Conclusions

In this paper methodological issues arising from the application of isovists for predicting spatial behavior and experience were discussed. The presented experiments investigated interrelations between spatial properties of environments, and spatial experience and behavior. The translation of qualitative theories allowed specific hypotheses on correlations between behavioral and spatial data that could be empirically approved. For experiential qualities and navigation behavior, already a few local isovist measurands were sufficient to widely explain the variance in the behavioral data. Vice versa, the empirical tests provided further insights into the actual relevance and characteristics of abstract spatial descriptor variables. By this integrative study, the authors hope to have elicited mutual interest in both the cognitive science and the space syntax community for the questions and methods of the other.

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