PSYCHOPHYSICS OF ARCHITECTURAL PROPORTION IN THREE DIMENSIONS

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Introduction

The theory of proportion in architecture has a long and convoluted history, in which the definition of proportion emerged as elusive and controversial. One source of difficulty is the multiple notions of the role proportion plays in experiencing architecture, in mathematical, perceptual and aesthetic discourses. As Roger Scruton (1979: 69) put it, "Precisely because proportion is so aesthetically fundamental that we should beware of tying it down to an explicit definition." In effect, architectural proportion has become one of the "words with lost meaning" (Scholfield 1958: 19). Attempts to clarify the role and significance of proportion have been made from three perspectives: symbolic (e.g., March 1998), aesthetic (e.g., Wittkower 1949), and perceptual-cognitive (e.g., Padovan 1991). The last two perspectives have often been conflated. For example, the historian of architecture Matthew Cohen pointed out that the two perspectives have often been grouped under the rubric of "proportion-as-beauty." He argued that "scholars and architects still commonly refer to 'harmony and proportion' without understanding specifically what these words mean, or realizing that by using them they are perpetuating an ambiguity that traces back at least as far as the early Renaissance" (Cohen 2014: 9). These are only few illustrations of the controversial nature of architectural proportion.

We confront this ambiguity by pursuing an interdisciplinary program of research that has the following points of focus. First, conceptions of proportion useful for architectural design should be defined for three-dimensional objects, rather than two-dimensional projections of objects. Second, differences between mathematically distinct proportions should be considered only after we have ascertained that the proportions in question are perceptually discriminable from one another. Third, perception of proportion should be studied from the point of view of a mobile person, which is the generic situation of experiencing architecture, in contrast to the artifice of static observer presumed by adherents of perspectival representation in architecture. Here we present first steps in pursuing these questions, concentrating on discrimination of proportions of three-dimensional objects.

Some of our thinking has been anticipated by the Dutch architect Hans van der Laan (1904-1991), who developed a proportional system for three-dimensional objects, and who investigated just discriminable differences in perception of proportions (Proietti 2021). Building on Van der Laan's work, we pursue the same issues using modern methodologies of sensory psychophysics and visual neuroscience (Pallasmaa

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and Robinson 2017; Albright, Gepshtein and Macagno, 2020; Gepshtein 2020). We describe a program of psychophysical studies (Proietti and Gepshtein 2020) designed to investigate human ability to discriminate proportions across spatial scales and conditions of movement.

The Research

Conceptual approach

Van der Laan developed the system of "plastic number" in the 1960s (Van der Laan 1983). Having studied the issue for several decades, he summarized human perception of proportion in terms of relations between three dimensions of objects (dubbed "plastic numbers") rather than the two dimensions considered by previous proportional systems. Series of plastic numbers cannot be reduced to familiar numeric progressions, such as the Fibonacci series in the definition of the golden section. This is because every step in the progression of plastic numbers represents a group of ratios characterizing objects at a certain spatial scale, where adjacent scales are just distinguishable. Van der Laan called these groups "types of size" (Figs. 1 and 2).

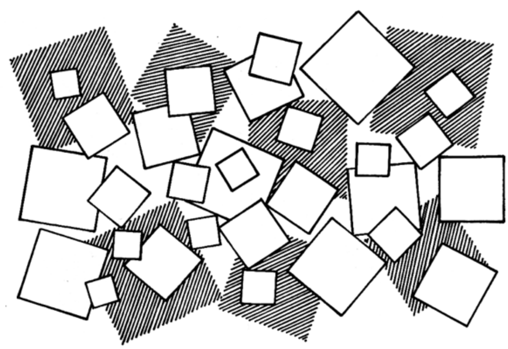


Fig. 1. An illustration Van der Laan's grouping experiment with 36 squares in a progression of sizes defined by the increments of the 1/25 margin of difference

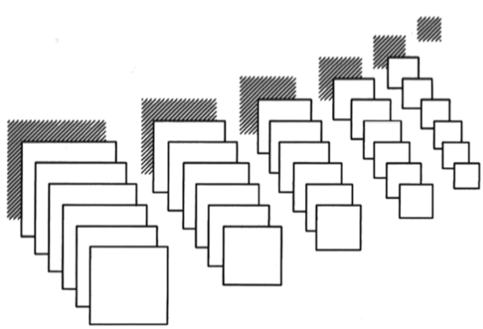


Fig. 2 Six families of size with seven members in each family determined by the proportional system of Van der Laan

> Our first intellectual contact with the size of things is restricted to the acknowledgement of a certain range within which we call things the same size. Precisely because of our inability to penetrate directly into the concrete size of things, we establish a range which accompanies each size as a margin. All concrete sizes within the limits of this margin answer to the selfsame image that we form of the size: they are all of the same type of size. Since the types of size have a constant proportion to the extent of their margins, they also succeed each other in a constant proportion (Van der Laan 1983: 54).

For example, each stop in the series of ratios 1:1, 3:4, 4:7, 3:7, 1:3, 1:4, 1:5, 1:7 is a "representative size" of a type of size. Thus, the type of size of 3:4 contains several members that differ by a quantity called "margin of size" that makes the members just discriminable from one another. Each other type of size contains such a set of just discriminable members (Proietti 2015).

In this approach, no single ratio is given priority, contrary to other proportional systems centered on a single magnitude of proportion, as in the systems of the golden ratio or the silver ratio (e.g., Navon 2011; Wall 2018).

Experimental approach

In our studies, human observers participate in psychophysical experiments that consist of a series of "trials" (Kingdom and Prins 2016). In each trial, the observer is presented with a pair of objects viewed through a pinhole (monocularly) or through a larger aperture (binocularly). The objects are parallelepipeds whose dimensions are determined by the proportional system of Van der Laan. One physical implementation of this system is called Morphotheek (Fig. 3). It consists of 120 pieces which we made using a computer-controlled cutting machine.

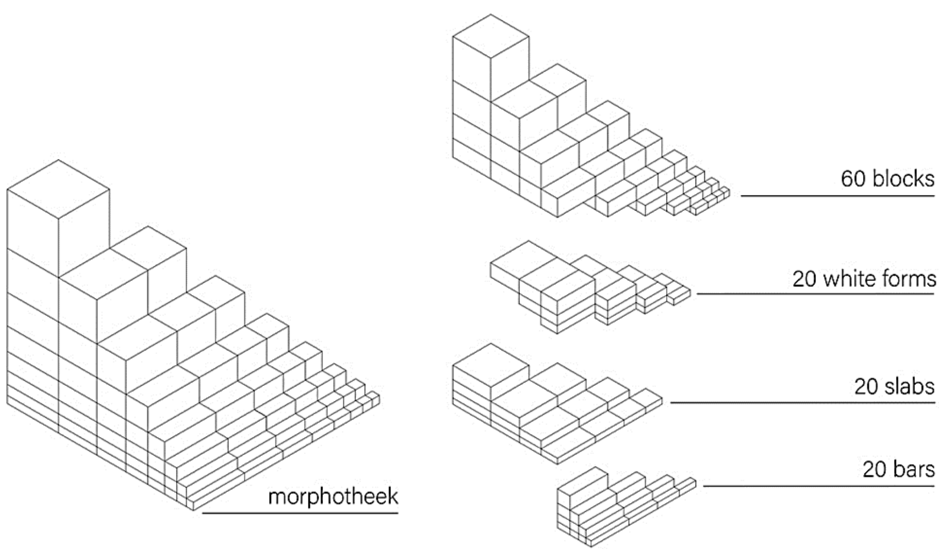
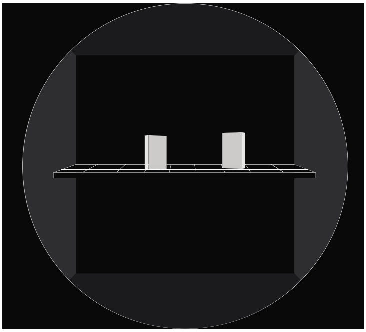


Fig. 3. Van der Laan's Morphotheek. 120 pieces of the complete Morphotheek system include objects of four kinds: 60 "blocks," 20 "slabs," 20 "bars" and 20 "white forms"



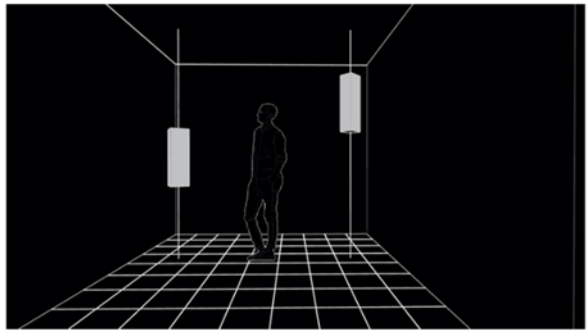


Fig. 4 (left) Stimulus view in the method of external observation
Fig. 5 (right) Stimulus view in the method of immersive observation

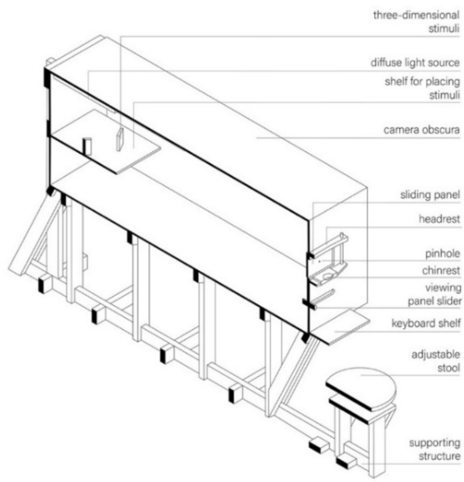


Fig. 6 (left). Sliding panel for binocular and monocular viewing in the device for external observation of proportioned objects. The half-open panel shows the subject's view

Fig. 7 (right) Axonometric section of the device for external observation of proportioned objects

We perform measurements using two approaches that differ by the method of observation: "external" or "immersive" (Figs. 4 and 5). In external observation, objects are presented inside a variant of camera obscura that affords monocular and binocular viewing (Figs. 6 and 7). Objects are placed inside the device, on a shelf marked with a rectangular 7 x 7 grid (Figs. 8 and 9). Each cell of the grid contains a series of diametric lines marking potential object orientations, with the step of 15 degrees. For each trial, the experimenter places a pair of Morphotheek pieces (called the "stimulus") on the shelf, at predetermined locations and orientation. The observer looks inside the device through a pinhole or aperture, and reports which object appears to have a larger proportion using a six-point rating scale. In immersive observation, the observer is seated or walking through a room, in which the objects are either suspended at different distances from the observer, or their images are projected on the walls. The observer's task is the same as in external observation.

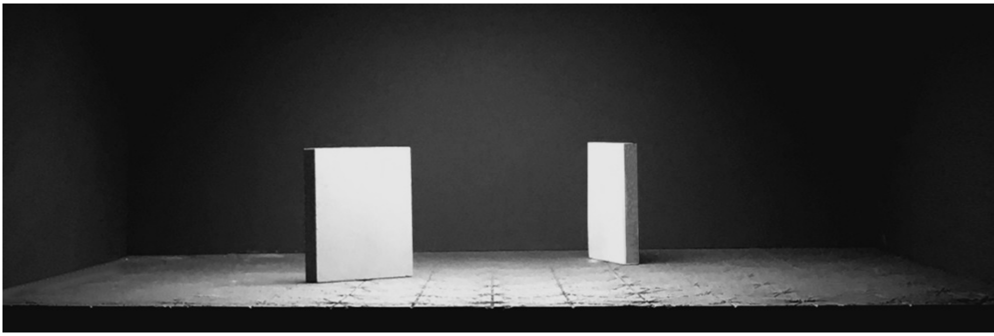


Fig. 8. Examples of the stimulus (two Morphotheek pieces) used in the external observation approach

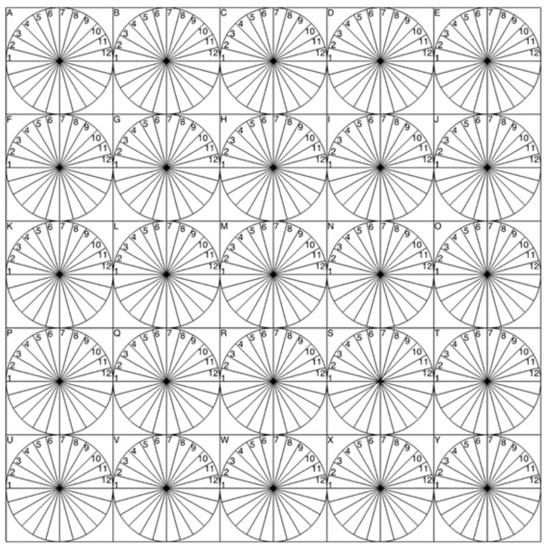


Fig. 9. The 7 x 7 stimulus grid for placement of stimuli

These settings allow us to measure observers' sensitivity to differences of proportion under multiple conditions of perspective distortion. The experiments just described implement the first two steps in our program of research, which is using three-dimensional objects to determine the boundaries of discrimination between proportions.

Conclusion

The growing interest in applying scientific methodologies to architectural theory and practice is an opportunity to re-examine the role of architectural proportion. We are developing an interdisciplinary program of research in which we use concepts and methods of sensory psychophysics and systems neuroscience to address controversies in the architectural theory of proportion. Using a novel measurement platform for investigating perception of proportion by static and mobile observers, we perform psychophysical experiments into the human ability to discriminate proportions of objects within and between spatial scales.

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