PLOT PERCEPTION

Perceiving Liveability through Objective Technology

Müjdat Deniz Şükür

MSc graduation project

Müjdat Deniz Sükür
4259742

P5 Report
MSc Urbanism
Graduation studio: Urban Fabrics

Mentors:
Dr.ir. Machiel van Dorst
Dr.ing. Steffen Nijhuis

External examinar:
Ir. Wouter Willers

Delft University of Technology

Apr. 2018

Acknowledgements

This book contains the final report of the graduation project 'PLOT perception', which is part of the research theme 'Design of the Urban Fabric', within the Urbanism trajectory at the Faculty of Architecture and the Built Environment at TU Delft.
'PLOT perception' is an explorative research on the visual perception of urban environments. It is explorative in the sense that it "borrows" methods and tools from the field of user experience (UX), and psychophysiology. By taking this sidestep; I hope to contribute to the indispensable relation between urban design and environmental psychology.

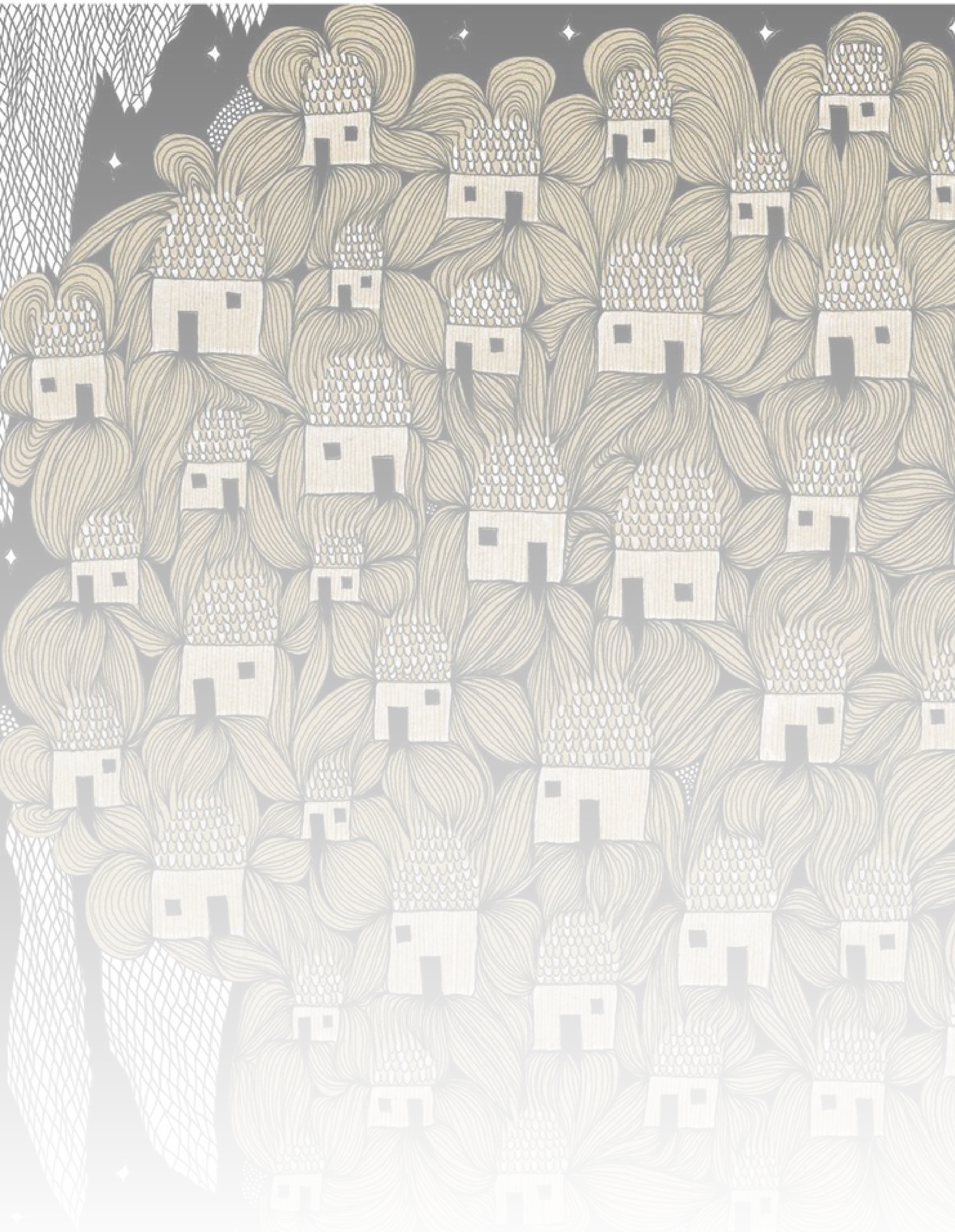
This project would not have been possible without the help and support of my mentors Machiel van Dorst, and Stephen Nijhuis.
I would like to thank both for their enthusiasm and by making this project possible, for the essential literature recommendations, clarifying insights, advice on methods and practicalities, and most importantly, for motivating and encouraging me in the graduation process.
I would also like to thank my family, friends, fellow students, and participants for their support; in particular Şebnem and Alper who have invested a lot of their spare time in the initial field runs and experiments. This accomplishment would not have been possible without their support. Thank you!

Deniz Şükür

Very true. And suppose further that the prison had an echo which came from the other side, would they not be sure to fancy when one of the passers-by spoke that the voice which they heard came from the passing shadow?

No question, he replied.
To them, I said, the truth would be literally nothing but the shadows of the images.

– Plato, 'The Republic, book VII. (360 B.C.)



Your gaze scans the streets as if they were written pages: the city says everything you must think, makes you repeat her discourse…
Barely does the eye light on a thing, and only when it ha recognized that thing as the sign of another thing: a print in the sand indicates the tiger's passage. It is the mood of the beholder which gives the city of Zemrude its form. If you go by whistling, your nose a tilt behind the whistle, you will know it from below: windows sills flapping curtains, fountains. If you walk along hanging your head, your nails dug into the palms of your hands, your gaze will be held on the ground, in the gutters, the manhole covers, the fish scales, waste paper. You cannot say that one aspect of the city is truer than the other…

Your footsteps follow not what is outside the eyes, but what is within, buried, erased. If, of two arcades, one continues to seem more joyous, it is because thirty years ago a girl went by there, with broad, embroidered sleeves, or else it is only because that arcade catches the light at a certain hour like that other arcade, you cannot recall where.

- Italo Calvino, The Invisble Cities (1979)

What is real? How do you define 'real'? If you're talking about what you can feel, what you can smell, what you can taste and see, then 'real' is simply electrical signals interpreted by your brain.

– Morpheus, The Matrix (2199)

PREFACE

My childhood years, like many of us I presume, I have spent the majority of my time walking, cycling, and playing in the streets between our house and school in my own neighbourhood. For me this was in Geuzenveld; a part of a typical post-war expansion plan which you can encounter in most Dutch cities, characterized by the rational stamp-like urban plan and mass social housing with monotonous architecture. As you grow older, naturally you expand your daily urban system, and with that also your mental image of the city.

During my high school years, I was travelling daily from my neighbourhood to my school in Amsterdam South, moving through different urban environments across the city. As little I knew about architecture and urban design back then, I remember still that I found it very intriguing how different parts of the city could affect your mood; how certain types of buildings could give you the excitement of “being downtown”, how green boulevards with trees could give you the feeling that you were in a wealthy neighbourhood, or even how brick cladding could evoke a feeling of “not belonging there”.

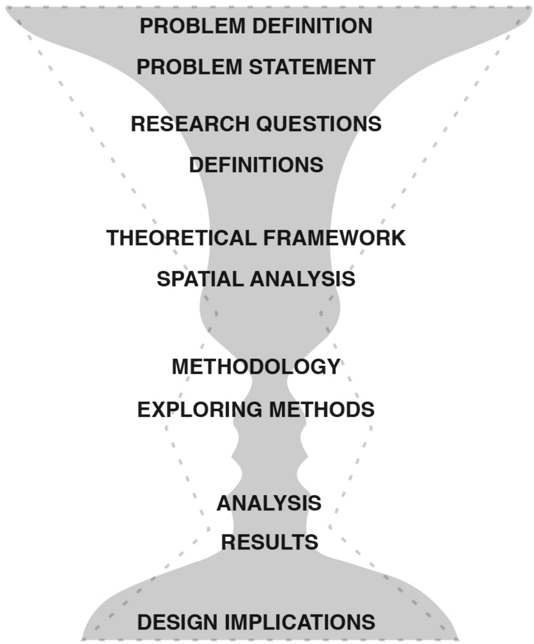
It is true that these are my own mental images of the city of Amsterdam, based on my own selective views and what I make of them, like the prisoner in Plato’s allegory, and my own experiences and uncertainties, like Calvino’s metaphor of the city of Zemrude. A person with different views, different experiences, and who grew up in –let’s say– the city centre of Amsterdam probably would give different meanings to the same images of the same parts of the city. Or, to make it more complex, a person who grew up in a country with absolutely no idea of the concept of a European city. I remember a friend of mine telling me the story about his visiting uncle, a stucco worker from rural Turkey, that was amazed about how many buildings were “unfinished”, referring to the Amsterdamse School style buildings in the Baarsjes.

As human beings, we also base our images on prejudices or more general cognitive biases: If I believe a certain neighbourhood is infamous for its high crime rates or unsafe areas, I would prematurely create a negative overall image before even entering the neighbourhood. Maybe the most influential factor in our experiences, the social layer is more essential in defining our mental images of the city, but then again I would question the difference in the feeling you would get when strolling around a residential area in Slotervaart and Buitenveldert; both areas with similar architectural ensembles, but with a different social structure. And what would happen if we could turn the hypothetical case around, and by that I mean to compare the feeling one gets when strolling around two architecturally different areas, but with a similar social structure? I would assume the spatial elements and their impact on our feelings and mental images of the city would be greater. In reality, the two are constantly interplaying with each other.

During the master's programme Urbanism at TU Delft, I continuously encountered the question on how to design certain elements. As someone with a planning background, who is educated into basing every step or statement on scientific research, empiric data or logic, I had very little experience with urban design, composition and form. It was especially difficult with design projects on the smaller scale, where intuitiveness and creative thinking were the decisive elements. It was in these projects that I somehow had to let go my critical and evidence-based way of thinking and lean more on my intuitive design skills. The problem was however, that I had little design experience. Loosening this critical thinking seemed more difficult, which resulted in a Sisyphean task: every time when I was on to something good, critical thinking came into play from another factor and counteracted the creative design process. Nonetheless this had pushed me into (re-) discovering great guidelines on urban or architectural design; ranging from Vitruvian principles to more modern "textbook" guidelines. The main goal was to search for useful knowledge and for an answer to what good design actually *is*, and how to achieve that. Another goal was to reflect on my own thinking processes and how to develop and improve a more creative and designerly approach, what we partly addressed in the essay 'The 2C: Creative and critical thinking' (Priniakanis & Sukur, 2015). The combination of these two "personal journeys" of getting to know the design discipline on the one hand, and a cognitive self-reflection on the other, had let me to the somewhat anti-climaxed discovery that *good design* is eventually in the eye of the beholder; or better yet, in the *perception* and *experience* of the beholder. This cliché had broadened my interests in how we actually perceive our built environment and opened up a new path into the discipline of environmental psychology.

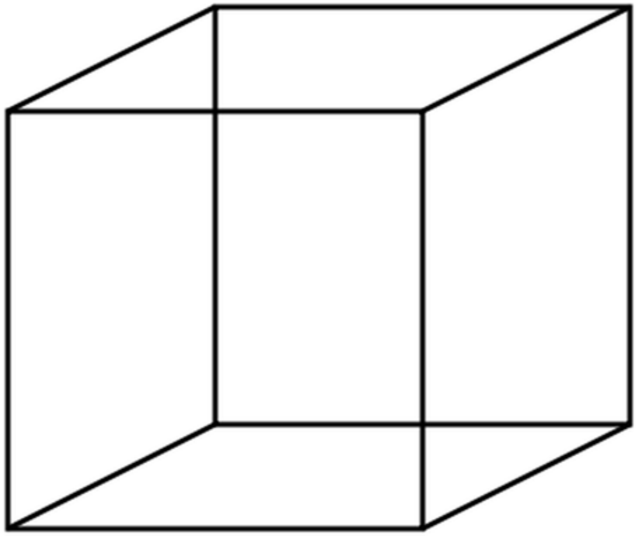
We are always talking about "experience" or "perception" and most research in planning or urban design often defines these terms in their behavioristic context. Practice shows that good design can be traced back to guidelines or patterns that are used as a holy grail for urban design (e.g. Alexander, 1977; Ching, 1979; Von Meiss, 1992). These imagery studies are based on great expertise of their authors and describe which elements work or do not work. Naturally, this expert attitude does not come out of nowhere and it is based on decades of practice, experience and design research. However, when it comes to the explanatory aspect, it remains rather cryptic. Even with these guidelines at hand, there are plenty of examples of imposing architectural or urban design cases from all over the world that have completely missed out on the user experience factor.

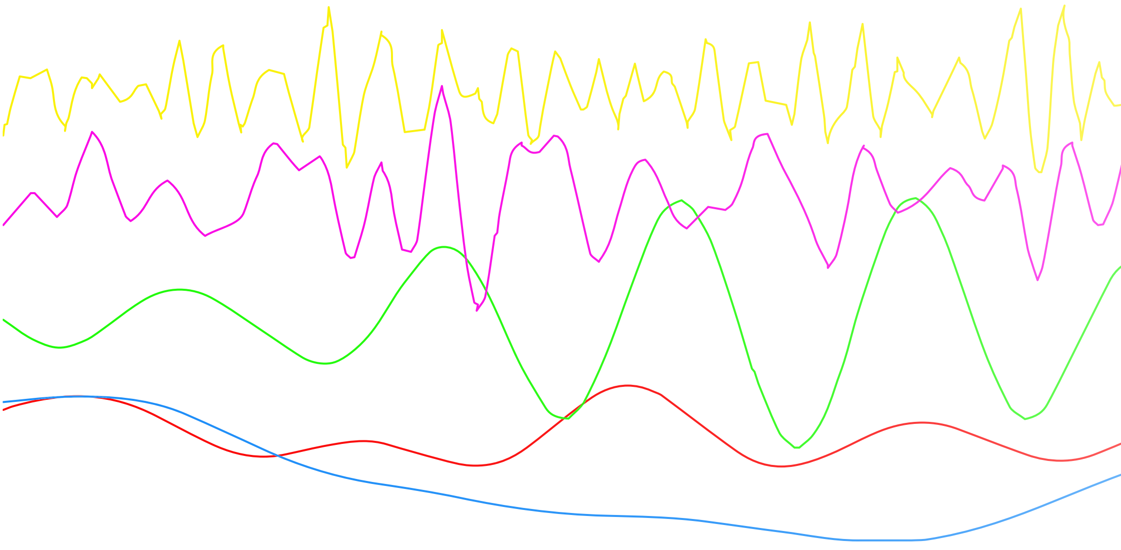
With a critical mindset, I was particularly interested in the question *why* and *how* these design guidelines work. Do we not take these guidelines for granted? Are they not outdated? Are they prone to be neglected in contemporary large-scale area development projects? Can we not revise and future-proof them? Because when we look at future urban development projects in general, we often see large-scale infrastructure, maglev trains, autonomous pods, or renewable energy-landscapes with lots of green in the renders, but with little attention to the human juxtaposition within the concept. When we look back to Le Corbusier's introduction of 'The Modulor' in 1950, we, ironically enough, see that the same principles of human proportion had failed to make it into the designs of public spaces in practice. We are currently experiencing a similar paradigm shift towards design with new technologies and visionary future concepts, where in terms of design and experience, we do not yet fully understand how these new urban environments will be experienced at the eye-level. It is therefore important to be careful and not to make the same misconceptions as urban designers did in the shift towards modernism. This research centralizes the human perception of space and aims to make it more explicit in future urban design.


PROBLEM DEFINITION
PROBLEM STATEMENT
RESEARCH QUESTIONS
DEFINITIONS
THEORETICAL FRAMEWORK
SPATIAL ANALYSIS
METHODOLOGY
EXPLORING METHODS
ANALYSIS
RESULTS
DESIGN IMPLICATIONS

CONTENTS

PART I





1. INTRODUCTION

In general, design is considered to be a complex, personal, creative and open-ended skill (Van Dooren et al, 2013). Generic design characteristics are ill-defined and unstructured or untamed and hard to evaluate in advance. Specific design characteristics on the other hand, are based on individual aspects of designers, differences in the design process and the type of artifact (Stolk, 2015). Based on the Construal Level Theory (Stolk, 2015: pp. 165), we can say that the larger the artifact is, the greater the psychological distance between the designer and artifact tends to get. This means that the urban designer has to develop greater skills at iteratively shifting back-and-forth from abstract thinking to concrete design steps.
At the other end of the design process, there are users who experience and assess artifacts differently. In the case of product design, quality is evaluated relatively easy with a set of criteria about function or form, while in the case of urban design, quality assessment is much more complex. The designed “artifact” has to cope with greater factors (e.g. population, mobility, ecology etc.), while people perceive and experience the everyday life of the built environment at eye-level. To extend on the complexity of urban design, we as human beings ourselves are part of the designed “artifact” itself, with each of us moving through a patchwork of urban streetscapes, with different modes of transport, in different tempi, sensing, reading, perceiving, learning and, more complexly, interacting with other complex *agents*[1] in the city.

Although we each assess our environment differently, many researchers from the field of environmental psychology explain how we assess and evaluate our environment (Berlyne, 1974; Kaplan & Kaplan, 1989; Nasar, 1994). As is mentioned in the previous chapter, the importance to explicate human perception of space is becoming more important over time. When designing through multiple scales, it should be elemental for the designer to know how people react to certain compositions and spaces.

1 Portugali et al, 2015: pp.59

Problem definition

How do certain designed elements influence our perception, cognition, mental image, emotions and eventually our behavior? These questions should be addressed in order to cope with rapid urban developments and the phenomenon of the city as a *complex adaptive system (CAS)*[2]. We are at the emergence of a paradigm shift towards what Jeremy Rifkin calls the 'Third industrial revolution' (Rifkin, 2011). With novel technologies such as the 'Internet of Things' (IoT) we are also moving towards new sensory and adaptive approaches in the field of urbanism, where objects are sensed or controlled remotely across existing networks of infrastructure to integrate the physical world into Big Data in order to be more accurate and efficient. As planners or urban designers, it is essential to withstand the human scale in this paradigm shift. We should not solely base our future designs on the objects sensing us, but also in how *we* sense and perceive our environments.

Problem statement

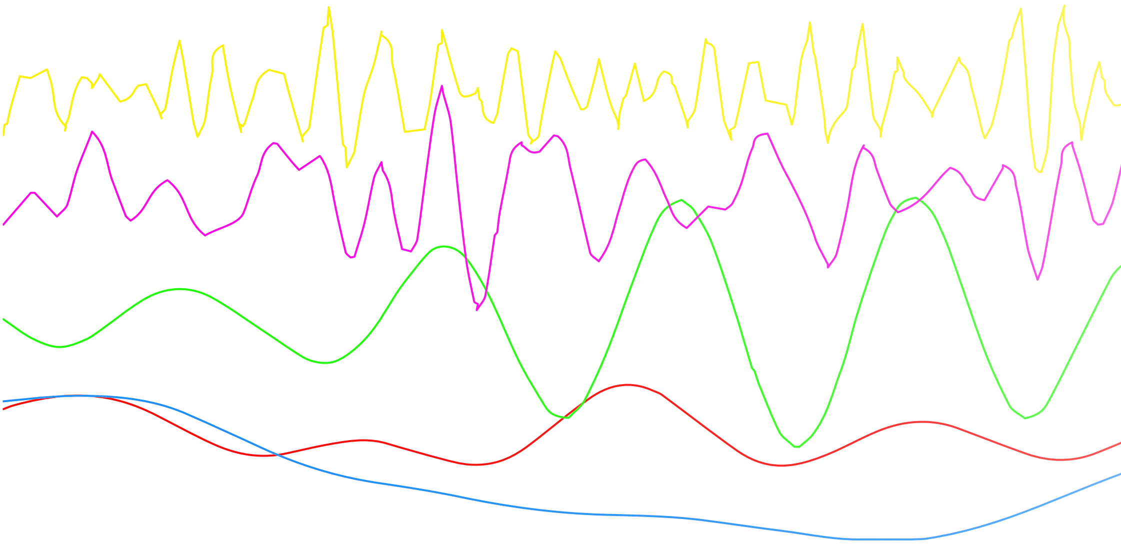
In the field of architecture and urban design, many practitioners and researchers discuss the occurrence of the physical space with its utilitarian meaning of function and use. Another approach, which is continuingly becoming prominent in the design process, assesses the quality of spaces or rather *places* (hence, the term *placemaking*) from a humanistic and behavioristic perspective. However, while the utilitarian meanings of function and use, along with its symbolic interpretation can change over time, the primary composition principles and elements of form and space comprise the timeless and fundamental vocabulary of architects and urban designers. These two approaches of form and function on the one hand, and use and behavior on the other, are discussed extensively in "classic" literature on urbanism. Nonetheless, while both approaches focus on the physical space and the juxtaposition of the human being within the physical world, a crucial, if not, the most important aspect of the relation between the two remains rather untouched or unintegrated: the *perception* and *cognition* of the built environment.

To integrate the aspects of form, function, behaviour and the actual perception, we need a better understanding of the human perception of the built environment. Many studies conducted on how people assess their environment are usually done with questionnaires or interviews. However, the problem with these qualitative methods is that there is a substantial loss of

2 Stolk, 2015: pp.233

information of the *actual* perception and *what* the interviewee writes down or answers at that given moment. People tend to forget the smallest experiences by the time they are supposed to enact them. This can be a positive thing when doing research on e.g. pre-attended cognition, but it is rather a convenience of available tools and methods than a choice (Dalgleish & Power, 1999). The second issue addresses the presumptive or hypothetical approach on perceptive research: the researcher only addresses questions which he or she assumes to be relative to the perception of the subject its environment. A third issue is that the interviewee always is biased in some extent by the interviewer or the questionnaire. A fourth issue is related to the first: not every detail is perceived consciously. A fifth issue is that statistically, the researched variables of interviews and questionnaires are usually measured with an ordinal scale: we cannot tell the *exact* difference between the values of a given scale (e.g. in a scale from bad=1 to good=5). The sixth issue concerns the scope and limits of environmental-psychological, psychophysical and psychophysiological research and their fields. The latter are usually done in laboratoria with extremely controlled settings, primarily focussing on a single set of stimuli, while the former addresses outside scenes. Because of the complex nature of the psyche, there exists little cross-disciplinary debate, and a mutual theoretical and methodological framework is far from reality. The last, but maybe the most important issue that this research aims to address, is the applicability of research outcomes into improvement of sensory and perceptual urban design. In general, we can say that the above methods provide little objective, and no empirical cross-dischiplinary research methods, and the researcher misses out on accidental (and potentially crucial) information of user experiences.

Current mobile sensory technology allows us to track eye movement and measure physiological activities in our body. There are several studies conducted in how our body reacts to certain environments by using skin conduction (Nold, 2009) or EEG sensors (Mavros, P., Austwick, M.Z. & Smith, A.H. (2016). Although these methods are fairly new in the field of urban research and only describe general findings, it allows us to get a step closer to an empirical approach to environmental perception and how, for instance, certain "textbook design principles" influence our perceptions and eventually our emotions in our daily urban environments. This research thus aims to add to the basis for future studies on the relation of psychophysiological perception of spatial elements. Detailed explanation of the methodology will be elaborated in chapter five.



2. RESEARCH QUESTIONS

Main research question:

*Which **spatial elements** are essential in influencing our visual **perception** of urban environments, and how can we explicate and express these elements in urban design?*

These broad definitions will be given on the next sections:

What is perception, and how does it work?
What are urban environments?
What are spatial elements?

Sub questions to systematically answer the main research question

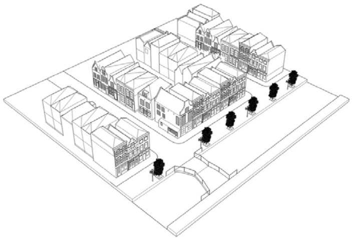
Can we find patterns of gaze behaviour, change in EEG frequency bands, and gazed elements?

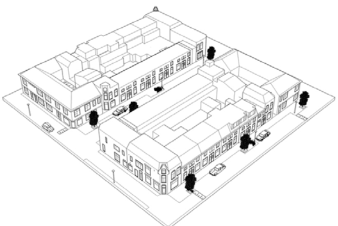
If so, when and how do these patterns occur, and what specific attributes do they have in common?

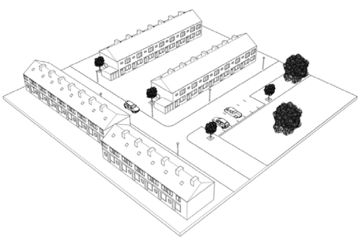
How can we express these attributes in urban design?

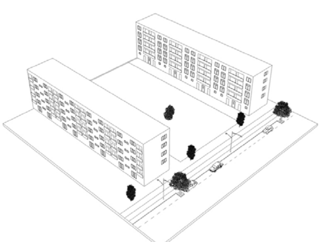
The following definitions will be elaborated in the theoretical framework:
EEG activity
Eye movement
Arousal
Appraisal
Emotion
Spatial elements
Design principles
Urban environments
Pre-attended cognition
Occasions

Definitions (main question)





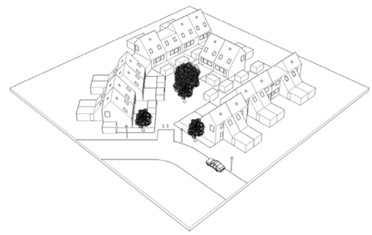




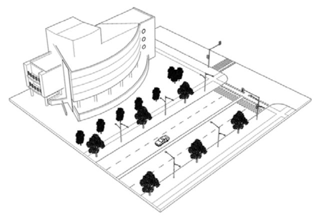
Perception (derived from Latin words *perceptio* or *percipio)* is the organisation, identification, and interpretation of sensory information *in order* to represent and understand the environment (Schacter et al., 2011). This definition implies that perception is a sequacious process with sensory inputs and cognitive aspects. Perception is not solely the passive receipt of these signals, but is shaped by learning, memory, expectation, and attention.
From the perspective of environmental psychology, environmental perception includes the ways by which we collect information through all our senses. (Gifford, 2002: pp. 21). Environmental *cognition* concerns the way we acquire, store, organize and recall information about locations, distances and arrangements in buildings, streets, and the great outdoors (Gifford, 2002: pp.32). However, according to Gifford, the concept of environmental perception is used rather inconsistently and often implies *assessment* and *appraisal* in practice.

A more technical (psychophysical and psychophysiological) definition of perception is given by Goldstein. All perception involves signals in the nervous system, which result from physical or chemical stimulation of the sense organs. In 'Sensation and perception' Goldstein elaborates on the perceptual process and describes the mechanisms that are responsible for perception, recognition and action (Goldstein, 2002). To understand the perceptual process in general, and to understand the measuring techniques used in this research, a multi-disciplined definition of perception from the approaches of environmental psychology, psychophysics and psychophysiology is elaborated in chapter four. The operationalization is given in chapter five.

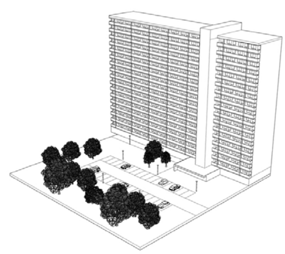
According to the authors of the definitions given above, **we** all perceive our environments differently. Perception is extremely complex and subjective. The way we perceive and give meaning to our environments are dependent on personal-, cultural-, and physical influences. This is the main reason why the population is sampled based on different attributes such as age, profession, and whether or not the subject is familiar with the area. With the scope of this research in mind, we cannot generalize our findings. However, we *can* validate the data if we relate different data from different attributes to each other and compare results to test hypothetical causalities.



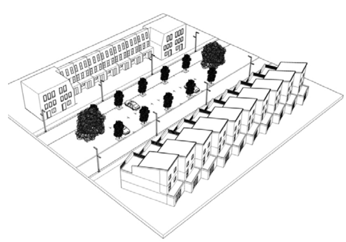
Many cities in a West-European context comprise of patchworks of **different urban environments:** from characteristic districts, blocks, squares, streetscapes to the buildings, trees and pavement materials. For this research a selection will be done on the basis of Thiels' definition of the urban scene, space, and occasion.

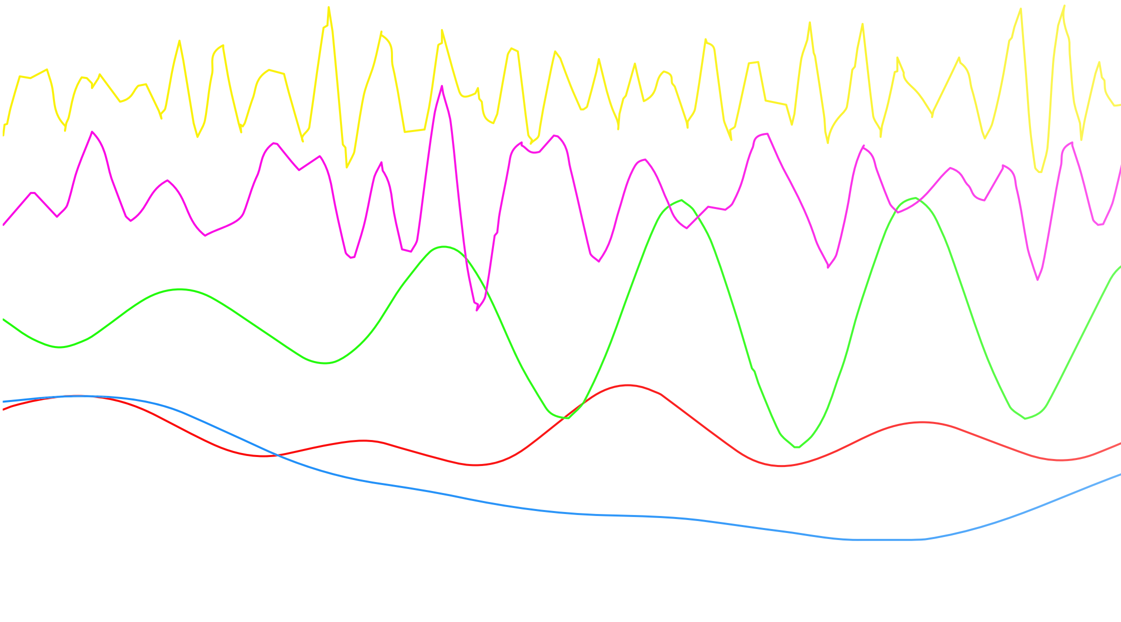


Basic **design principles** are defined here by combining different guidelines (Von Meiss, 1992; Ching, 1979; and Alexander, 1977). These are: (symmetrical) axis, hierarchy, contrast, rhythm/repetition, datum, complexity, and transformation. Throughout the research special attention will be given to these guidelines to study causalities in environment and perception.



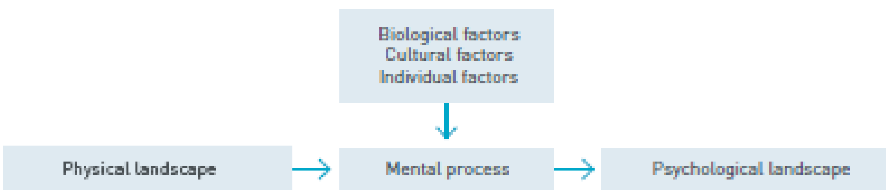
According to **appraisal** researchers, emotions are elicited by an appraisal, which is a non-intellectual, automatic evaluation of the significance of a stimulus for one's personal well-being (Scherer et al, 2008).





3. THEORETICAL FRAMEWORK

In the second chapter of 'Exploring the visual landscape; advances in physiognomic landscape research in the Netherlands', a basic yet comprehensive model is given for studying the psychology of visual landscapes. This model is essential for keeping the general overview of an otherwise complex and cross-disciplinary process that involves multiple overlapping, interrelated, and indistinctively defined factors.



Default pre-disciplinary landscape research model (Nijhuis, van Lammeren & van der Hoeven, 2011)

As is stated by Jacobs in the same chapter, and as we shall notice in the following sections, research on the visual perception of landscapes so far, is done rather fragmented and dispersed across disciplines, without a mutually connected theoretical framework. A body of theoretical and empirical insights, along with substantial cross-disciplinary debate has not yet emerged. However, there *are* sets of theories such as arousal theory (Steffen, 1975; Berlyne,1974; Nasar, 2008), preference matrix (Kaplan & Kaplan, 1989) and the prospect-refuge theory (Appleton, 1975) that are widely accepted and partly explain in how we perceive our environments (Jacobs, in Nijhuis, van Lammeren & van der Hoeven, 2011).

Environments, scenes, spaces and places

In 'People, Paths, and Purposes: notations for a participatory envirotecture', Phillip Thiel coins the important term "user-participant" (UP) while describing the physical environment as *"…a sequence of physical stimuli available at the UP's sensing envelope over a given interval of time and at a specific point or along a specific sequence of points in space."* (Thiel, 1997; pp. 131). This denotes the uniqueness of the UP its attending capabilities (attended stimuli) and subjective conversion (spatial cognition) of the sequence of stimuli into his or her own phenomenological environment. These patterns of stimuli can be distinguished into *affordances* (first coined by Gibson, 1979), *behaviour settings* and *activities*, where the first can be identified as entities that affords actions when perceived, such as a path, stairs, a platform or a cliff. The second influences our behaviour and can be identified as e.g. bedroom, café, highway or courtroom. The last implies activities (e.g. commuting, lunch, or lecture). Together, these terms describe our world stage where we are moving in. The environment (EN) is *"…a path-contingent sequence of these scenes and can be represented schematically by a number of adjacent overlapping areas, each denoting a specific scene."* (Thiel, 1997; pp. 131).

Space

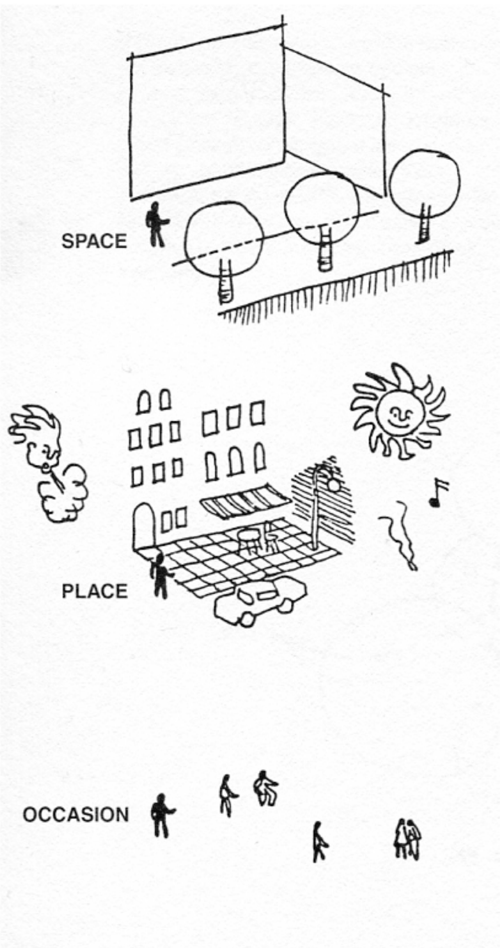
We can decompose a scene into three basic components:
1. Space: A more-or-less discrete and delimited volume affording human occupation and movement therein. Within spaces, space-establishing elements (SEE's) define boundaries of the space its areal and volumetric form and extent, and indicate physical possibilities of movement therein. Aside the physical boundaries, virtual social restraints, such as property boundaries, crosswalks, and lane-dividers are also considered as SEE's: objects, screens and surfaces.

Place

2. Place: Referring to the further perceptual qualification of a space to achieve an identity as a particular behaviour setting, a place is the result of the perceived positional relationships of various SEE's by the UP at a given time and position. The anonymous space becomes "dressed" into a more specific individuation (transformation where personal and collective unconscious are brought into consciousness) by the furnishings which are called place-qualifying agents (PQA's).

Space is thus an abstract and theoretical conceptualization. The spaces we encounter are to some degree tangibly furnished. We are then required to describe the physical attributes of these furnishings, which provide the expression of place.

3. Occasion: The presence and activity of the human occupants in the place, in accordance with some implicit or explicit program. As in PQA's, the sense of occasion is determined by the perception of members of humanity (MH's) by the UP at a given time and point



Space, place & occasion (Thiel, 1997)

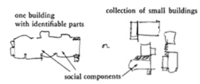
Elements of architecture, Form, Space, and order

In 'Architecture: Form, Space and Order, Francis Ching describes the fundamental elements of architecture with an analogy made to learn the alphabet first, to subsequently create words, syntaxes, essays, novels etc. The book starts with primary elements such as points and lines and gradually covers form, space, organizations, circulation, proportion, scales and ordering principles. In the overview, the perceptual element of architecture is described as: "sensory perception and recognition of physical elements by experiencing them sequentially in time." These are then specified as: approach & departure; entry & egress; movement trough the order of spaces; functioning of, and activities within spaces; and the quality of light, colour texture, view, and acoustics (Ching, 1979; pp.13). These terms are in line with Thiels' affordences, behavioural setting, and activities. Ching however, describes the importance of composition and ordering principles as visual devices that allow diverse forms and spaces to co-exist perceptually and conceptually in harmony. Order without diversity can result in boredom, while too much diversity without order can create chaos. As will be explained later on, these ordering principles are in clear alignment with arousal-, and appraisal theory within psychology (Kaplan & Kaplan, 1989; Nasar et. al, 2008).

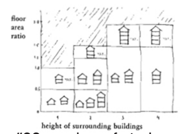
Von Meiss further denotes the phenomenon of order and disorder in the third chapter of 'Elements of Architecture' and describes the factors of coherence, such as repetition and similarity, proximity, and the interaction of these factors. He then states that the relation between architectural elements can be more or less organized, starting from the use of a uniform texture, developing into gradation, hierarchy, contrast, contradiction, and complexity, to a collection of elements without identifiable relationships, in other words, chaos. In general the rule of thumb is that, the fewer *links* there are in the visual information that the observer receives, the greater the effort he or she has to make (Von Meiss, 1993). For instance: a large and bright abstract building in the shape of a cube in a natural landscape is easily perceived by the observer due to its contrast (in size, shape, texture and colour) in the organic and complex scene, while a single tree has no identifiable visual relation with a forest. These structural and ordering principals are overlapping and therefore can be confusing. For practical reasons I have defined the structural and ordering principles into the following: axis (of symmetry), hierarchy, contrast, rhythm, datum, complexity, and transformation.

Ordering principles (author)

In the seventies, Christopher Alexander, along with his colleagues have published a set of books that were meant as a statement to set a new basis for an entirely new approach in architecture, building and planning. The core of their second work 'A Pattern Language' was the idea that design relies on a certain "language" that provides articulation and communication, and that with a formal system that gives coherence to this language, people should design their own environments; the complete opposite of the dominant blueprint planning rationale at that time (Alexander, Ishikawa, & Silverstein, 1977). The articulation and communication provided in the said patterns, provides us an embedded method to give globally accepted meaning to the earlier defined spatial elements. Given the scope of this research, I refer to patterns that occur from the neighbourhood-level on:

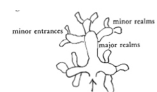


#95 building complex

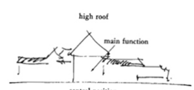


#96 number of stories

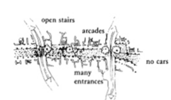
#97 shielded parking



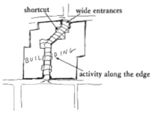
#98 circulation realms



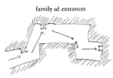
#99 main building



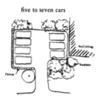
#99 pedestrian street



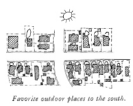
#101 building throughfare



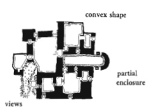
#102 family of entrances



#103 small parking lots



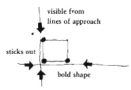
#105 south facing outdoors



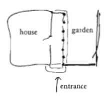
#106 positive outdoor space

#108 connected buildings

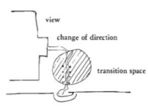
#110 main entrance



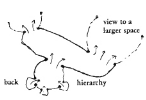
#111 half-hidden garden

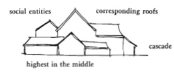


#112 entrance transition



#114 hierarchy of open space



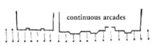


#116 cascade of roofs

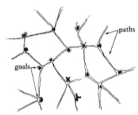
#117 sheltering roof

#118 roof garden

#119 arcades



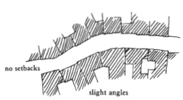
#120 paths and goals

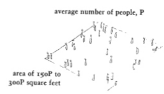


#121 path shape

The path shape formed by fourteen houses.

#122 building fronts

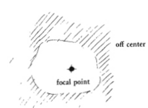




#123 pedestrian density

#124 activity pockets

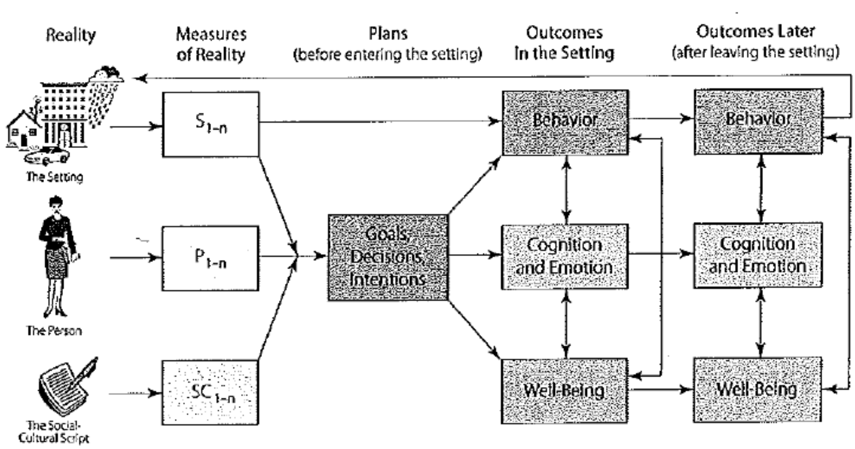
#125 stair seats



#126 something roughly in the middle

In general, the field of environmental psychology is guided by seven major theoretical approaches: In *stimulation theories* the physical environment is conceptualised by complex sensory information. Within this theory, the adaption-level approach gives the assumption that people adapt to a certain level of environmental stimulation. Optimum (arousal) stimulation, restricted environmental stimulation, and stress theories are examples within stimulation theory. *Control theories* are based on the importance of an individual's real, perceived, or desired control over stimulation and boundary regulation. *Ecological psychology* emphasizes the importance of person-environment behaviour relation by focusing on naturally occurring small-scale socio-physical patterns of behaviour. *Integral approaches* such as interactionism and organismic theory describe the full and complex interrelations of persons and setting. *Operant approaches* specify abstract principles and adopt a direct problem-solving approach that employs behaviour modification techniques. *Environment-centred* theories and ecopsychology raise the issue of the environment its own welfare and its ability to support our own well-being. *Social psychology* based theories explain which factors affect environmental behaviour from the social aspect (Gifford, 2002). The framework of this research leans towards integral approach, but eventually aims for a problem-solving approach.

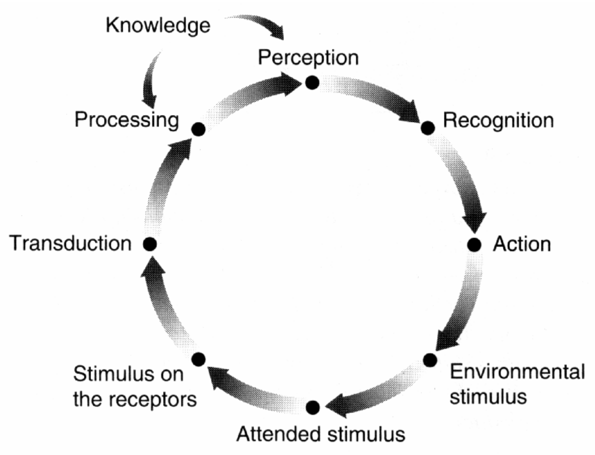
According to Gifford, environmental perceptive research is in contrast with traditional perception research. In traditional perception research, he states, researchers assume that understanding simple stimuli is necessary to understand the complex stimuli in daily life. The traditional approach prefers examining the perceptual process in laboratoria where external influences are controlled. Environmental psychologists in contrast, embrace the complex stimuli as large-scale scenes and treat these as whole entities. This dichotomy in perception research is based on what William Ittelson calls *object* perception and *environmental* perception.



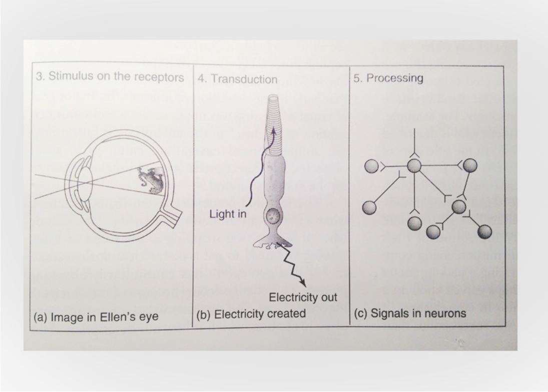
A comprehensive overview of environmental psychology (Gifford, 2002)

Sensation, perception, and action

All perception involves signals in the nervous system, which result from physical or chemical stimulation of the sense organs. In 'Sensation and perception' Goldstein elaborates on the perceptual process and describes the mechanisms that are responsible for perception, recognition and action with the addition of knowledge to the perceptual process. This allows us to make an important distinction between top-down, and bottom-up processing in Goldstein's perceptual process. When we follow the process from stimulation of the visual receptors to transduction and neural processing, we refer to *bottom-up* processing. The presence of knowledge acknowledges that the brain is not an empty computer waiting for signals to process, but rather is stored full of knowledge, facts, memories, and expectations that we bring to a certain situation. Processing that begins with the effect of knowledge a person brings into a perceptual situation refers to *top-down* processing. The visual information is essential in determining whether or not a process is bottom-up. Current physiological studies have for instance acknowledged Koffka's assumption that Gestalt stimuli are prioritized and happen instantaneous (Marini & Marzi, 2016)



The perceptual process (Goldstein, 2002)



Stimulus, transduction, & processing (Goldstein, 2002)

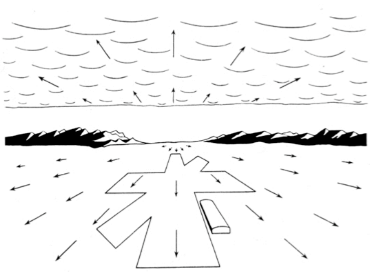
Relations & studies in the perceptual process (Goldstein, 2002)

Relationship				**How studied?**
A.	Stimulus	⟶	Perception	Psychophisically. Present a stimulus and determine the person's response.
B.	Stimulus	⟶	Physiology	Physiologically. Present a stimulus and measure the electrical response in the nervous system; also look for connections between anatomy and perception.
C.	Physiology	⟶	Perception	Physiologically and psychophysically. Measure physiological and perceptual responses to the same stimuli.

Seeing & visual perception, dorsal stream, ventral stream. Processing object analysis

In 'Seeing' Frisby & Stone give a schematic overview of two important visual pathways from our eyes to the visual association cortex. Retinal images enter the eye (through the V1 & V2 system) and are projected on the occipital lobe (V4). The dorsal stream that accounts visuo-spatial and visuo-motor processing happens in the posterior parietal cortex. The ventral stream accounts sto object analysis (the what) and is located in the inferior temporal cortex (Frisby & Stone, 2010; Zeki, 1995).

Gibson however, partly abandons this Keplerian description of optics, and approaches the visual perception from an ecological perspective. An important theory in visual perception that is first coined by him (1979) is the theory of *affordances*. Surfaces around us *afford* a certain behaviour (e.g. sit on a chair, push, or pull a door, etc.), however are only afforded when perceived right. This theory abandons the optical phenomena of the *visual field* and the simple representation of retinal images in our primary visual cortex described before, and primarily relays on the perceived information that the medium, whether it is a surface, object, place, or person, affords. Other theories that are relevant for the subject of this research, and partly based on the principles of Gestalt psychology are that of *direct perception,* and *information pick-up.* These theories question the meaning of sense, and the relationship between stimulation and stimulus information (e.g. radiant light vs. ambient light). The traditional conceptions about visual sense, based on light and the corresponding sensations of brightness are not elements of perception, and the inputs of the retina are not sensory elements on which the brain operates, because visual perception can not only fail by the lack of stimulation, but also by the lack of stimulus information, giving the basics for visual perception through optical flow: "*In homogeneous ambient darkness, vision fails for lack of stimulation. In homogeneous ambient light, vision fails for lack of information, even with adequate stimulation and corresponding sensations.*" (Gibson, 1979; pp.54). This theory of optical information has a close relationship with Von Meiss' earlier mentioned *links* of visual information that the observer receives.



Optical flow (Gibson 1979)

Sensory information (author)

Complexity

Contrast

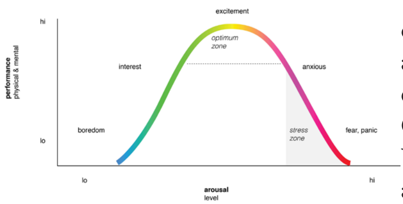
Order

Texture

Visual links (Von Meiss 1992)

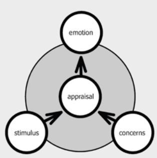
Arousal theory

In ‘Psychologie van de ruimtelijke omgeving’ Steffen distinguishes perception in the broad sense, and the perception in a strict sense. In the broad sense, perception comprises everything that we perceive consciously, which includes perceived images, recognitions, thoughts, fantasies, lust disorders, tensions, and behavioural impulses. In the strict sense, perception refers to the feeling-aspect as distinguished from the knowledge-, and strive-aspect. It thus emphasizes a subjective, emotional, or affective state in which one relates. In both senses, the theory of arousal-level measures the condition of heightened consciousness, watchfulness, and alertness. An environment with high complexity and variance conceives higher activation and arousal. The arousal level is most evident with strong emotions such as fright, fear, or surprise (Steffen, 1981). One of important phenomenon in arousal theory is the Yerkes-Dodson law, which dates back to 1908, and predicts a parabolic relation within the axes of arousal (motivation) and performance while performing a task: Too much arousal leads to anxiety and stress, while too little can result in boredom. The optimum arousal level lies within the middle. Berlyne adds to this, that if the arousal drops below a certain level, the subject will seek stimulation in e.g. exploratory behaviour (Berlyne, 1971).



Appraisal

According to appraisal researchers, emotions are elicited by an appraisal, which is a non-intellectual, automatic evaluation of the significance of a stimulus for one’s personal well-being. Scherer et al. give the example of going on the first date: If the date is perceived as positive, one might feel happiness, joy, excitement etc., because the person had appraised the event as to having a positive effect on the long-term (relationship, engagement, or marriage), and thus evokes positive emotions. However, in cognitive sciences these appraisals are deemed to be very subtle and hard to measure, as the main controversy on the theory argues that emotions cannot happen without physiological arousal. However, as is mentioned before, there are examples of legible low-tech models such as the preference matrix (Kaplan & Kaplan, 1989), which we can use to define subject appraisal afterwards. These post-evaluative methods however are usually rather based on convenience, than a choice (Dalgeish & Power, 1999).



As is explained in Goldsteins' perceptual process, at a certain point, after attending stimuli, transduction occurs, where stimuli are transduced in electrical signals (neuron firing). A firing neuron leads to voltage boost inside the cell. An incoming signal triggers sodium ions into the cell, which leads to voltage change, resulting in a higher voltage inside the cell, compared to the outside. After reaching a threshold through the difference of fast influx of sodium ions and the slow outflux of potassium ions, an action potential is triggered in the form of electrical discharge that travels through neighbouring neurons. This event that lasts for about two milliseconds changes the voltage from the resting potential of -60mV to +20mV. This electric activity that is captured by electrodes on the surface of the skull thus represents the field potentials resulting through combined activity of many neuronal cells. Electric waves that are captured the clearest derive from neural activity of the cortex, which are closest to the electrodes. (Oude Bos, 2006).

Understanding EEG

Although deeper structures like the thalamus and brain stem cannot be measured directly (which MRI and fMRI analyses can provide), and the captured signals are distorted by bone and tissue in-between the electrode and the cortex, EEG provides important insight of cortical activity through recorded patterns in frequency and amplitude. The captured frequencies range from 1 to 100 Hz and are grouped in frequency bands, as specific frequencies are more prominent in certain states of mind.

Five brain waves in general:

Gamma (40 – 100 Hz) γ
Involved in higher processing tasks as well as cognitive functioning.

- **Too much Gamma Waves relate to:** Anxiety, high arousal, stress
- **Too little Gamma Waves relate to:** Depression, learning disabilities
- **Optimal Gamma Waves relate to:** Binding senses, cognition, information processing, learning, REM sleep

Beta (12 – 40 Hz) β
Associated with normal waking consciousness and a heightened state of alertness.

- **Too much Beta Waves relate to:** Anxiety, adrenaline, high arousal, inability to relax, stress
- **Too little Beta Waves relate to:** Daydreaming, depression, poor cognition
- **Optimal Beta Waves relate to:** Conscious focus, memory, problem solving

Alpha (8 – 12 Hz) α
Dominant during quietly flowing thoughts, daydream or during light meditation

- **Too much Alpha Waves relate to:** Daydreaming, inability to focus, too relaxed
- **Too little Alpha Waves relate to:** Anxiety, high stress, insomnia, OCD
- **Optimal Alpha Waves relate to:** Relaxation

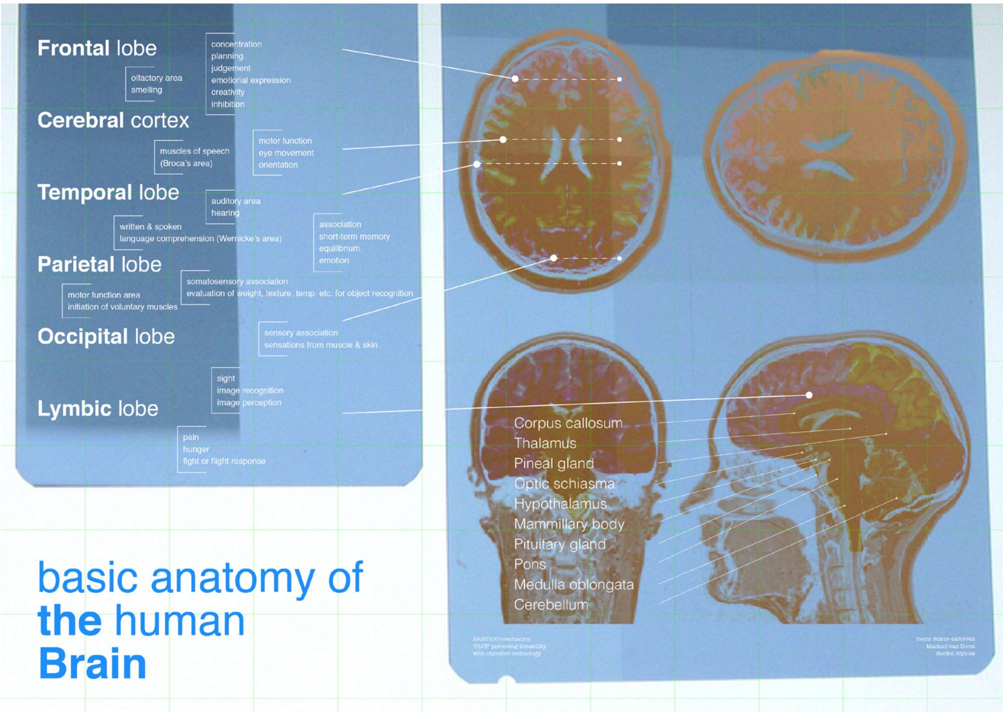
Theta (4 – 8 Hz) θ
In a dream; vivid imagery, intuition and information beyond normal consciousness and awareness.

- **Too much Theta Waves relate to:** depression, hyperactivity, impulsivity, inattentiveness
- **Too little Theta Waves relate to:** Anxiety, poor emotional awareness, stress
- **Optimal Theta Waves relate to:** Creativity, emotional connection, intuition, relaxation

Delta (0 – 4 Hz) δ
Experienced in a deep dreamless sleep and in very deep transcendental meditation.

- **Too much Delta Waves relate to**: Brain injuries, learning problems, inability to think
- **Too little Delta Waves relate to**: Inability to rejuvenate body, inability to revitalize the brain, poor sleep
- **Optimal Delta Waves relate to**: Immune System, natural healing, restorative sleep / deep sleep

(Oude Bos, 2006; Mavros, Austwick & Smith, 2016; Aspinall et al, 2013; Teplan, 2002; Sawant & Jalali, 2010; Lee & Hsieh, 2014)



Understanding EEG (author)

Emotion representation

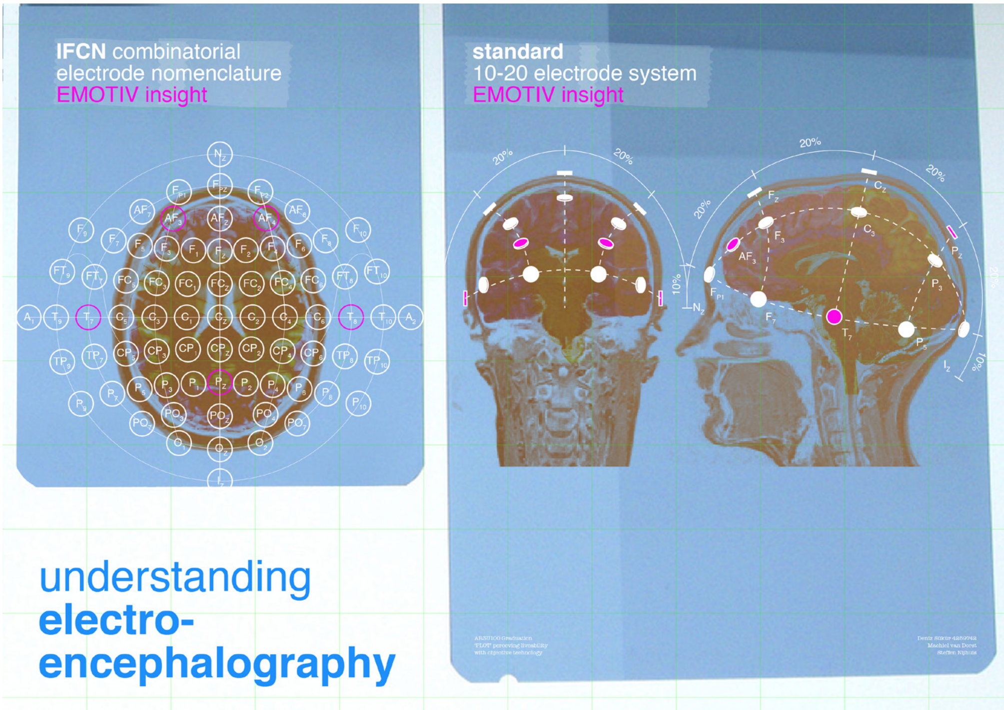
Emotion representation

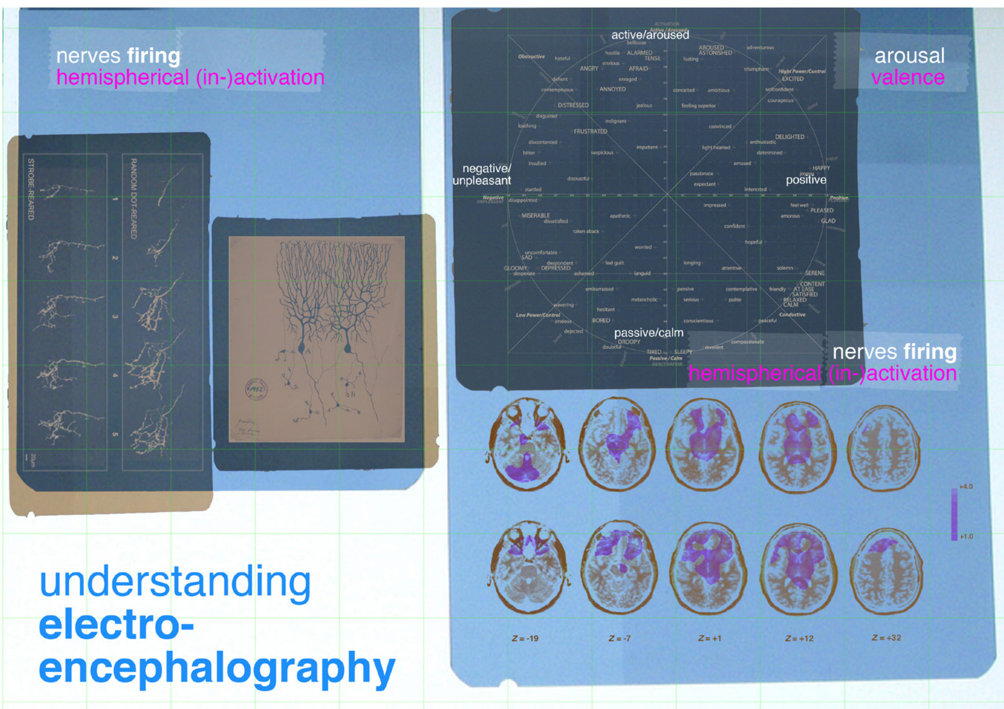
To define emotion, a Darwinian approach gives us eight basic emotions: anger fear, sadness, disgust, surprise, curiosity, acceptance and joy (Ekman, 1992). The representation of emotion through brain activity brings us to the cognitive approach to emotion and gives us Lang's two-dimensional scale according to valance (positive/negative) and arousal (calm/excited). This method is used in Oude Bos' study on EEG in brain-computer interface. Oude Bos states that valence is closely related to hemispherical or cortical laterality, or in other words: whether an emotion is positive or negative, is closely related to (in-)activity in the cortical hemispheres (left or right part of the brain). Left frontal inactivation is an indicator of a withdrawal response, connoted with negative emotion. Right frontal inactivation is a sign of an approach or positive response. Oude Bos then observes the differences between alpha and beta bands. Higher level of alpha activity and a decrease of the beta band imply low brain activity. However doing literature review on hemispherical and cortical laterality had opened a broad discussion whether or not the theory can be generalized.

Capturing emotion with the commercial EEG headset: EMOTIV Insight

Limits of capturing emotion

Although a lot of studies have been done in BCI, EEG and emotion detection, emotion representation through hemispherical laterality is an ongoing discussion. The Emotiv Insight EEG sensor provides software which includes the detection of their following emotional states: instantaneous excitement; long term excitement; stress; engagement; relaxation; interest/affinity, and focus. The methodology here is not published transparently, however, a recent research based on this exact equipment shows correlation with EMOTIV's classification and emotional responses of subjects having an insight (Cernea, Kerren & Ebert, 2011). For evaluating positive, or negative perceptions in this study, a more convenient qualitative method is used. The EEG data in this study is used to measure the relative alertness.

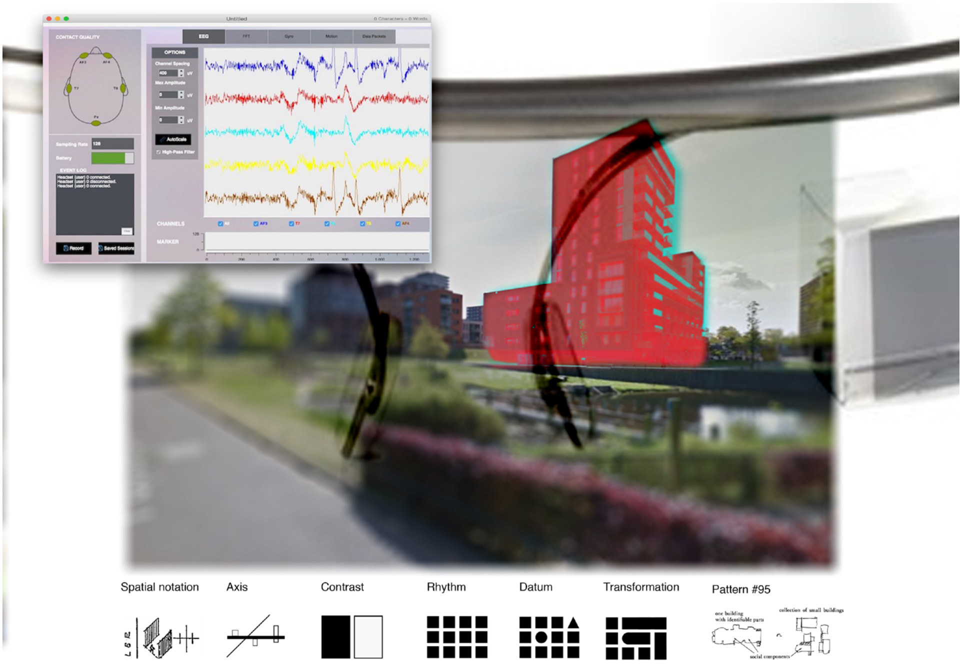


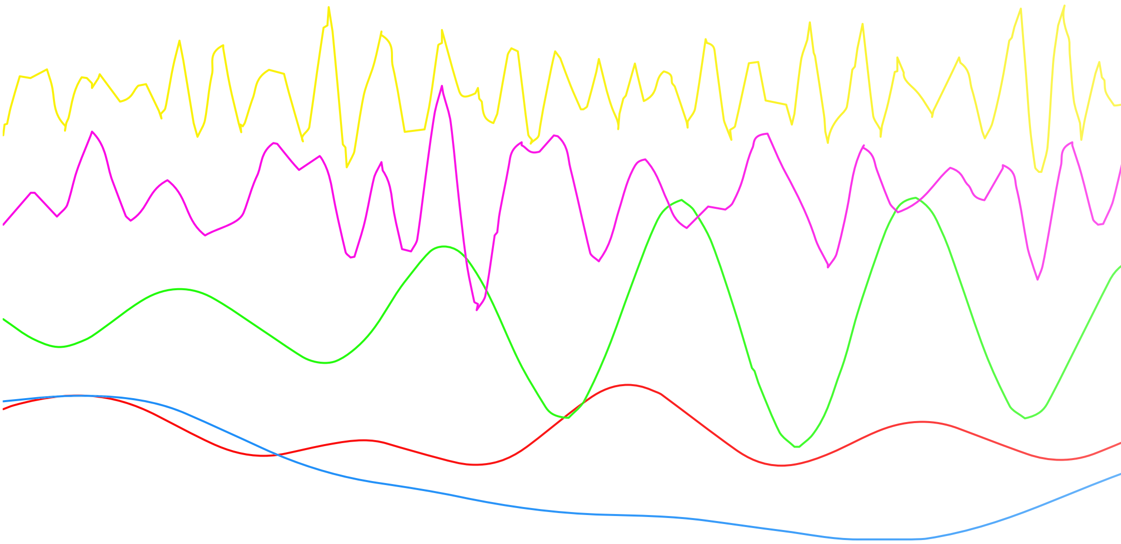


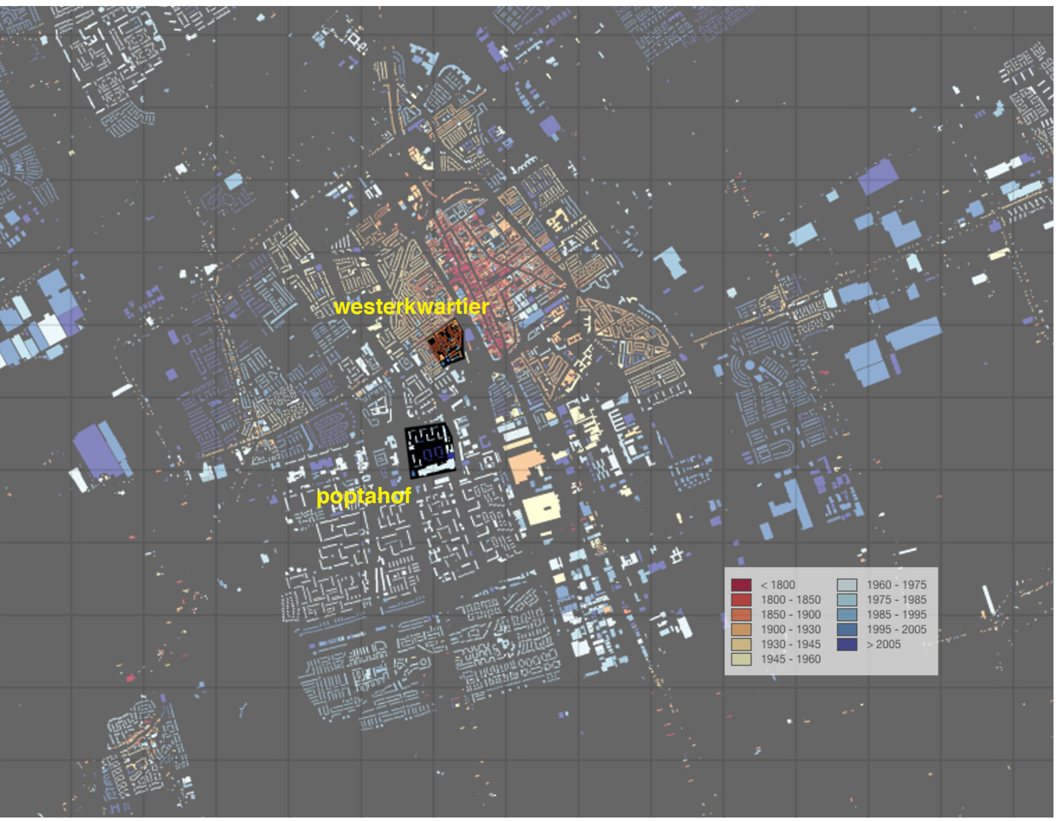
Understanding EEG (author)

Eye tracking

In order to look for relations between EEG data and spatial elements, an eye-tracking device will detect what subjects observe as visual stimuli inputs. The eye-tracking device records both the visual field and pupil movement of the observer. Eye-movement and the visual field are then calibrated to fixate a focal point on the actual attended stimulus.







Poptahof & Westerkwartier in Delft (code waag, edited)

4. SPATIAL ANALYSIS

In the theoretical framework chapter, we have described some of the greatest works on the topic of urban design, environmental psychology and the basics in how we perceive our environments. This chapter focuses on the link between what is mentioned in the theoretical framework and the spatial elements that occur and characterize the two cases of 'Poptahof' and 'Westerkwartier' in Delft.

When it comes to analyzing the urban context or urban environments, there are countless ways in how to approach and carry out the analysis. In the introduction and problem statement, we have briefly mentioned how the city acts as a complex system. In urban design studies therefore, the analysis method is usually defined by a (set of) ill-defined problem(s) that the analyst tries to foreclose, emphasize and communicate into design inputs. This spatial analysis however focuses on hypothesizing present spatial elements within the two cases, that theoretically have the biggest potential in influencing on our visual perception. Elaborating on on what is discussed in the theoretical framework, the following analysis first tries to *narrate* the cases based on terms of Alexander's pattern language from the neighbourhood level on. Second, the analysis aims to objectively *describe* sequences and scenes by bluntly, i.e. without giving spatial elements any kind of meaning, looking at physical space-establishing elements (SEE's), place-quality agents (PQA's), and how the primary, secondary, and tertiary spaces are composed (Thiel, 1997). Thirdly based on the researches of Lynch, Steffen, Cullen, and von Meiss, we change the perspective to the eye-level and try to *capture* frames with the most valuable sensory information per scene.

Poptahof

Up until 2006, Poptahof was a typical 1960's post-war neighborhood, characterized with its rational and functional plan, based on the CIAM (Congres Internationeaux d'Architecture Moderne) ideology. The general idea behind the CIAM its 'Functional City' concept was to improve life by designating separate zones for each function such as living, working, recreation, and traffic. With the post-war baby-boom, the massive increase in auto-mobility, the large housing shortage, and the influx of guest-workers and immigrants from former colonies, on the national policy agenda, these super-efficient urban plans had made their ways into implementation all over the Netherlands (and Europe). Like their masterplans, the associated modernist architecture is also based on function and efficiency, focusing on maximizing space and light for the dweller. The general result was an archetypical high-rise gallery flat, which was then repeated to a certain extent. Poptahof (designed by van Embden) is part of Voorhof and was built in 1964, during the peak of the rational planning era, where urban plans were aimed at composing whole neighbourhoods as districts (Van Dorst, 2005). With a nod towards social engineering, plans included a geometrical composition of high-, medium-, and low-rise buildings in each neighbourhood, a shopping centre in the middle, and an elementary school in each smaller centre.

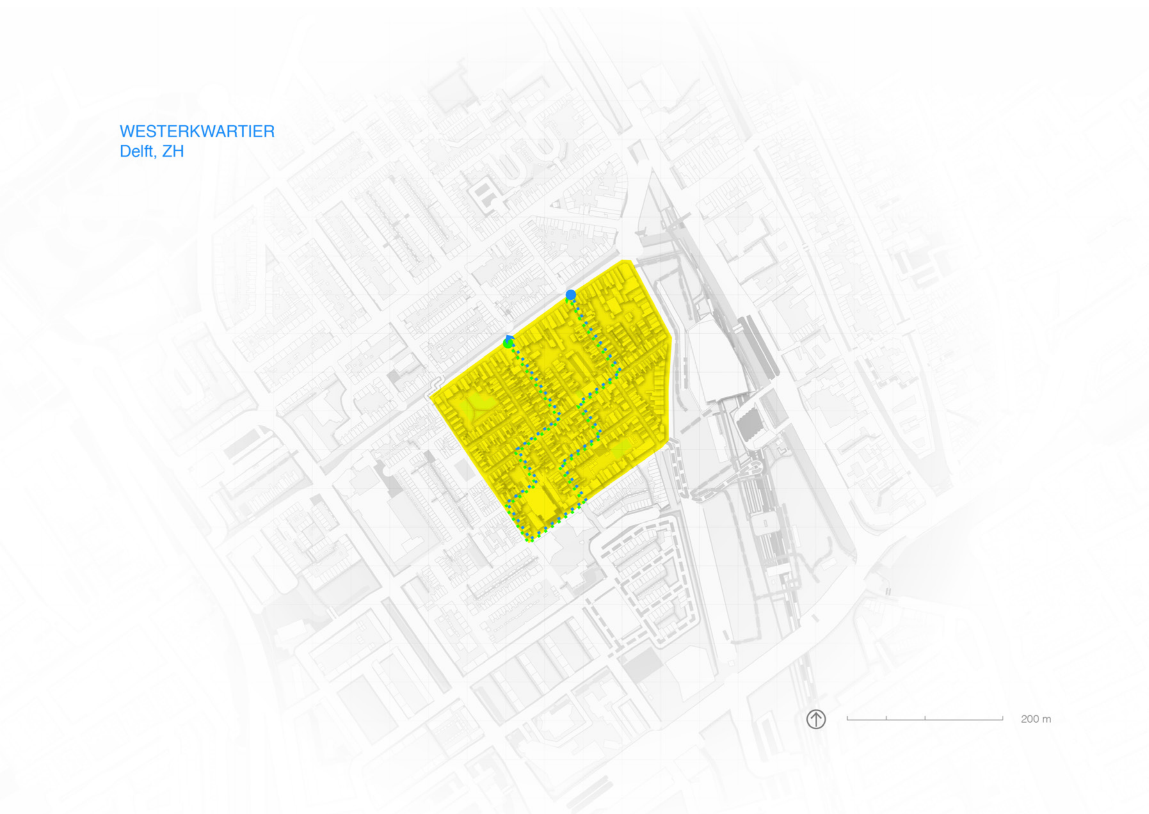
In the 1990's there were plans to renovate the high-rise flats and demolish the medium-rise bulidings. Due to protests of local shop owners however, the renovation plans were only done partly. In 2004 'Palmbout Urban Landscape' was commissioned by the municipality to restructure the neighbourhood. The park in the centre was re-designed and oriented as the heart of the neighbourhood. The main idea was to pervade the character of the park to the residential areas by opening up building envelopes to create a visual link from the semi-public courtyards to the park in the centre. Raising the ground level of the new building-courtyards would allow coverage of car parks and at the same time, create a series of interesting semi-public spaces. The newly built complexes are noticeably different than the older gallery flats.

POPTAHOF
Delft, ZH

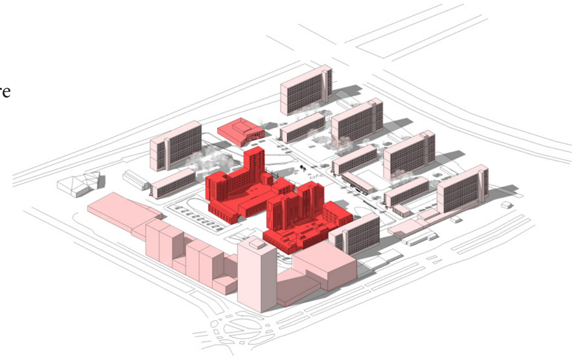
Westerkwartier

The 'Westerkwartier' neighbourhood is in the district of 'Hof van Delft' and is situated directly to the West of Delft central station. Along the 'Buitenwatersloot' (literally meaning outside-water-ditch), was the area where the first buildings outside the city wall were built in the late middle ages. In 1847, when the first national railroad was expanded to The Hague and Rotterdam, Delft became an important location for sawing mills, distilleries, factories, and later after the opening of the Technical University, also for chemical industry. The booming industry naturally caused an influx of factory workers, who all needed housing. In reaction to the housing pressure in 1879, municipal architect de Bruyn Kops drew the expansion plan for Westerkwartier, which was designated with rows of cheap housing for factory workers and more prominent houses for the middle class facing the station.

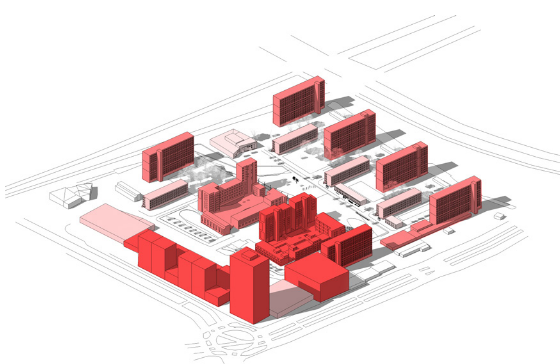
In the late 1970's the neighbourhood was impoverished, too densely built, with the lack of public space, greenery, and parking facilities. While the municipality wanted to demolish and rebuild the area, the local neighbourhood committee had organised a protest, leading to the demolition of only 124 houses in order to make room for public space and green, and renovation of existing housing. The architecture in the neighbourhood is still dominated by typical 19th century worker's housing, which is characterized by rows of two-story brick-cladded houses, with each house having its own front door, a living quarter, bedsteads, and an attic. The fragmented ownership in the area is visible on the colourful personalized façades, front stoops, and different roofs. Buildings in the corner vary from the rows and are usually chamfered, and accentuated with façade ornaments.


WESTERKWARTIER
Delft, ZH
200 m

#95 **Building complex**
A building represents a manifestation of a social group or social institution and therefore should be, like the group or institution itself, devised into visible smaller entities to make it more interactive with humans. The image shows buildings and their rate of identifiable parts.

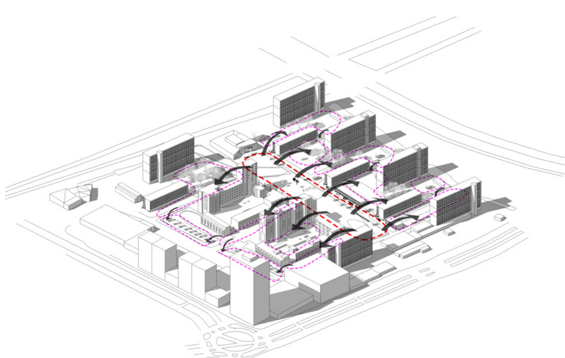


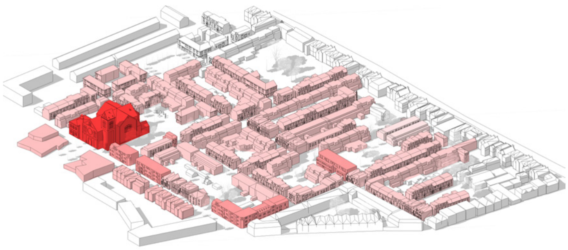
#96 Number of stories
High buildings destroy the townscape, they destroy social life, promote crime, and wreck open spaces near them. A maximum of four stories is preferred, with a FAR of max. 0.5 for single story, 1.0 for two story, 1.5 for three story, and 2.0 for four story buildings.



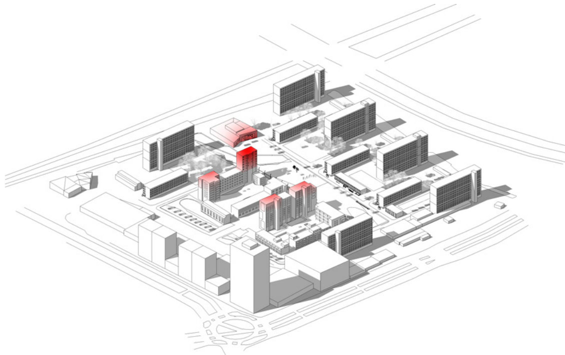
#97 Shielded parking
Large parking lots are inhuman and nobody wants to walk past them. If you are driving however parking lots are the man entrance to the building. Putting large parking lots behind natural shields gives the opportunity to create a gateway to the building. The image shows all visible parking lots.

#98 Circulation realms
Buildings and collection of buildings need a clear structure and hierarchy of realms where one passes through them in a sequential manner. It is better if each of them are distinctive and have some sort of gateway.

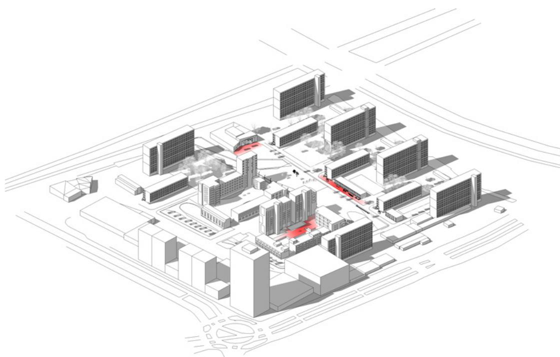




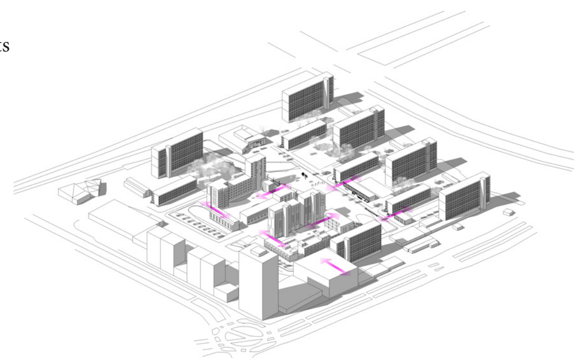
#99 Main building
In the words of the authors: “a complex of buildings with no centre is like a man without a head”. For any collection of buildings, the most essential building, the soul of the group, should be higher or more prominent, so that the eye goes immediately to the most important part



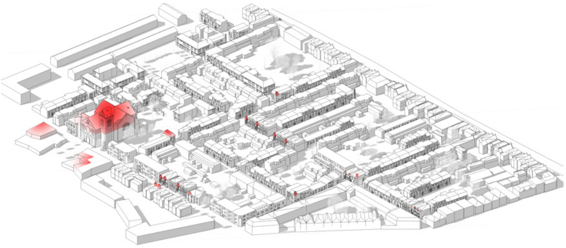
#100 Pedestrian street
One of the most essential social “glue” in society is to create social intercourse in the street. Buildings therefore must be arranged so they form pedestrian streets with many entrances and open stairs directly from upper stories to the street. By allowing circulation as much as possible oriented towards the street, movement between buildings becomes movement on the street.

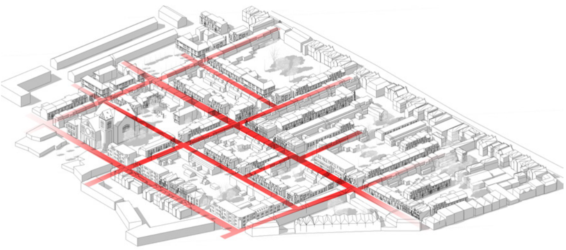


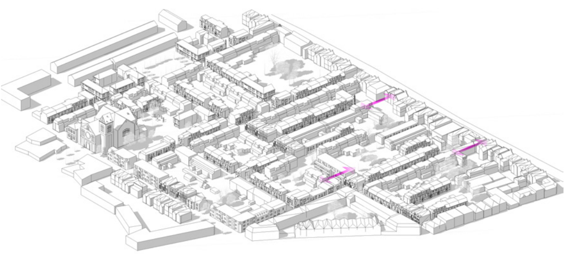
#101 Building thoroughfare
Building throughways not only offer shortcuts and free loitering. When designed properly, entering a public space through doors, corridors, changes of level etc., tends to keep away people without specific goals in their mind.



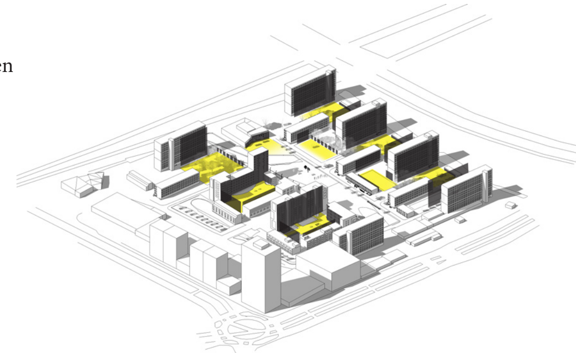
#102 Family of entrances
To avoid confusion and to improve a clear lay-out entrances should form a “family”. This means that they should each be visible from the others and should be broadly similar.



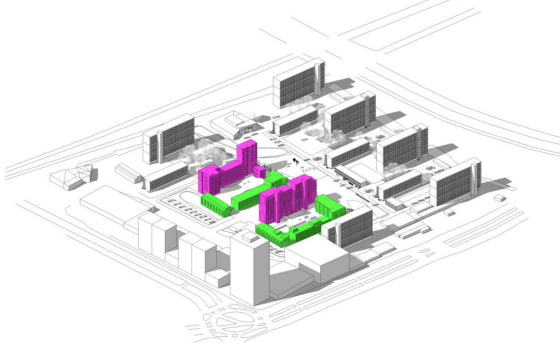




#106 Positive outdoor space
Outdoor spaces, which are "left over" between buildings, will, in general, not be used. It is preferred to create convex spaces with enclosure from e.g. building wings, trees, hedges, fences, arcades, and trellised walks. The space should become an entity with positive quality and not spill out indefinitely around corners.

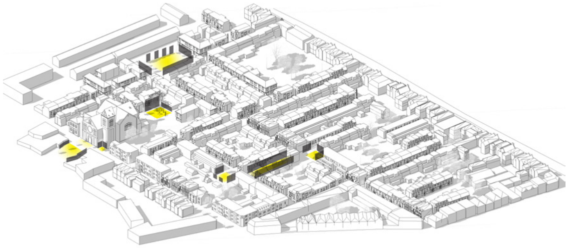


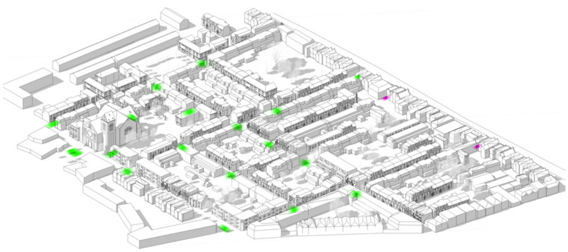
#108 Connected buildings
Isolated buildings are symptoms of a disconnected society. Referring to psycho-social disintegration at the emotional level, a town with disconnected buildings would depicture a society made up with disconnected and isolated selves.



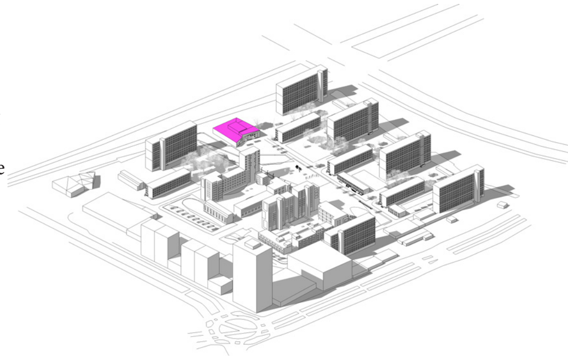
#112 Entrance transition
The experience of entering a building influences the way we feel. If the transition is too abrupt, there is no feeling of arrival. "Street behaviour" and "crowd behaviour" differs from the way we behave inside buildings. A neater transition destroys the momentum of the closedness, tension, and distance, which are appropriate to street behaviour. Transitions should be marked with a change of light, sound, direction, surface, level, enclosure, and above all, with a change of view.

#114 Hierarchy of open spaces
People always try to find a spot with their backs protected and with a view to a larger opening, beyond the immediate space in front of them. It is therefore essential to create smaller spaces that form a natural back, with openings and views towards at least one larger space.





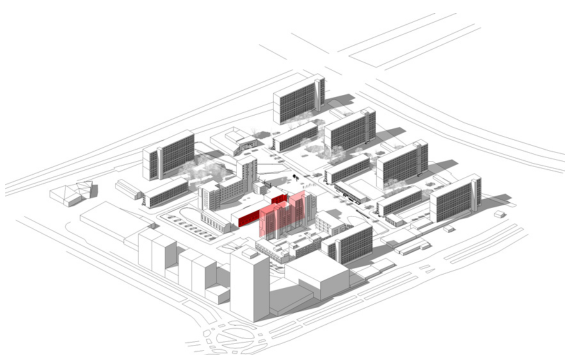
#117 Sheltering roof
The roof plays a primal role in our lives. It is not only the sheltering function that is essential; the roof also must include the living quarters within the roof shape. Otherwise, it would just be a cap on top of a building. There is empirical evidence that the geometrical sloped roof-shape is deeply rooted in our psyche and thus also provides “psychological” shelter.

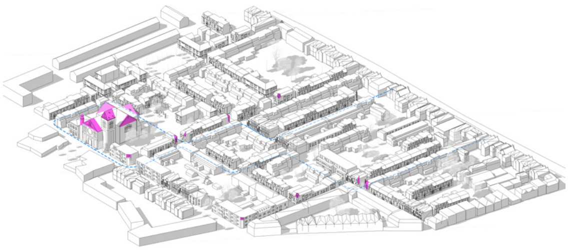


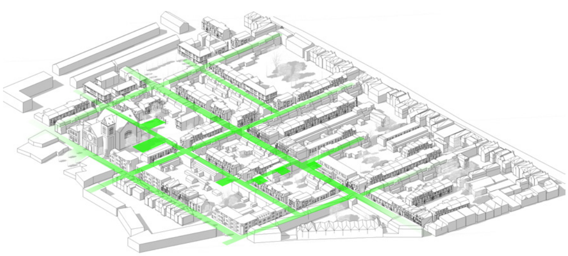
#120 Paths and goals
The process of walking is crucial for the layout of paths. As we walk, we scan the landscape for intermediate destinations and try to walk in a straight line towards these. We arrange our walking paths in a way that we pick a temporary goal – a clearly visible landmark – which is more or less in in the same direction. As we get closer, we pick another goal so in the meantime we can think or daydream, without thinking about our walking direction every minute. If there aren't enough intermediate goals, the process of walking consumes unnecessary emotional energy.

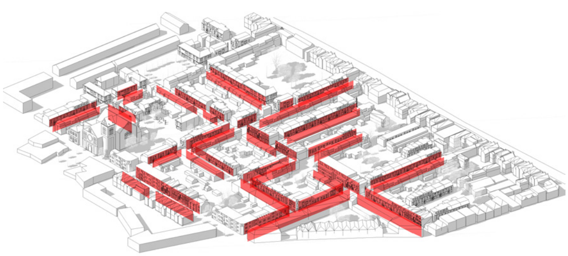
#121 Path shape
Streets should also be for staying in, and not just for moving through. By creating a bulge in a path, and by making the ends narrow, you create a focus on an enclosure where people could stay in.

#122 Building fronts
Building set-backs from the late 20th century where aimed at creating more light and air, while they also destroyed the street as a social space. It is essential to create building fronts with the mindset that they also create streets and spaces in front of them. On no account should there be set-backs. Buildings should face the street directly, preferably with a slightly uneven angles emphasize the shape of the street.

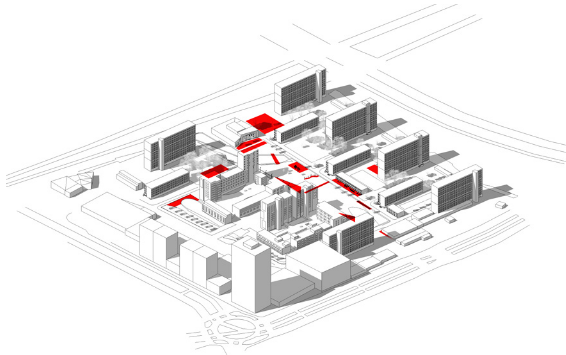




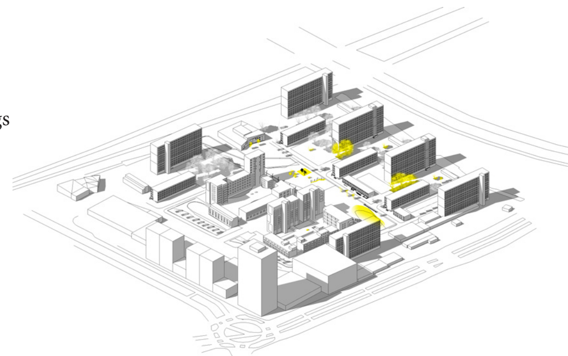


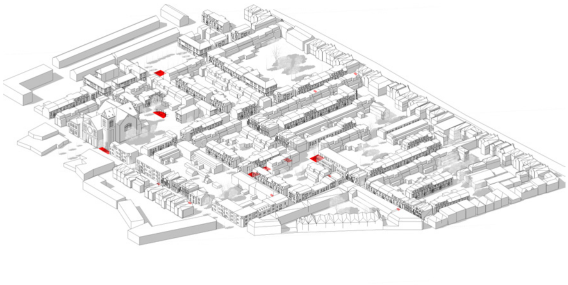


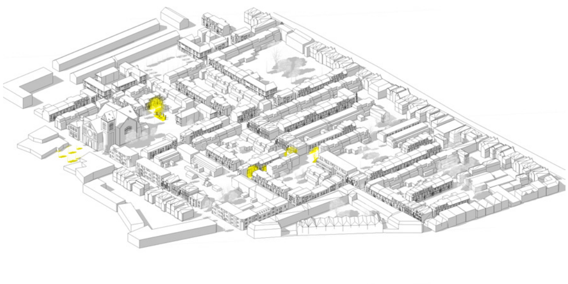
#124 Activity pockets
The life of a public square depends on the activities on the edges. If the edges fail, the space can never become lively.



#126 Something roughly in the middle
A public space without something in the middle is likely to stay empty. We have seen earlier that people prefer protected positions with their backs turned to objects or buildings and face the open space. If we put an object, a tree, statue, or a fountain in the middle of a square, the same effect of offering protection applies to this object. Alexander gives an example by referring to a deeper instinct to put something on the table in the middle of the room. This however could be better explained by affordances.



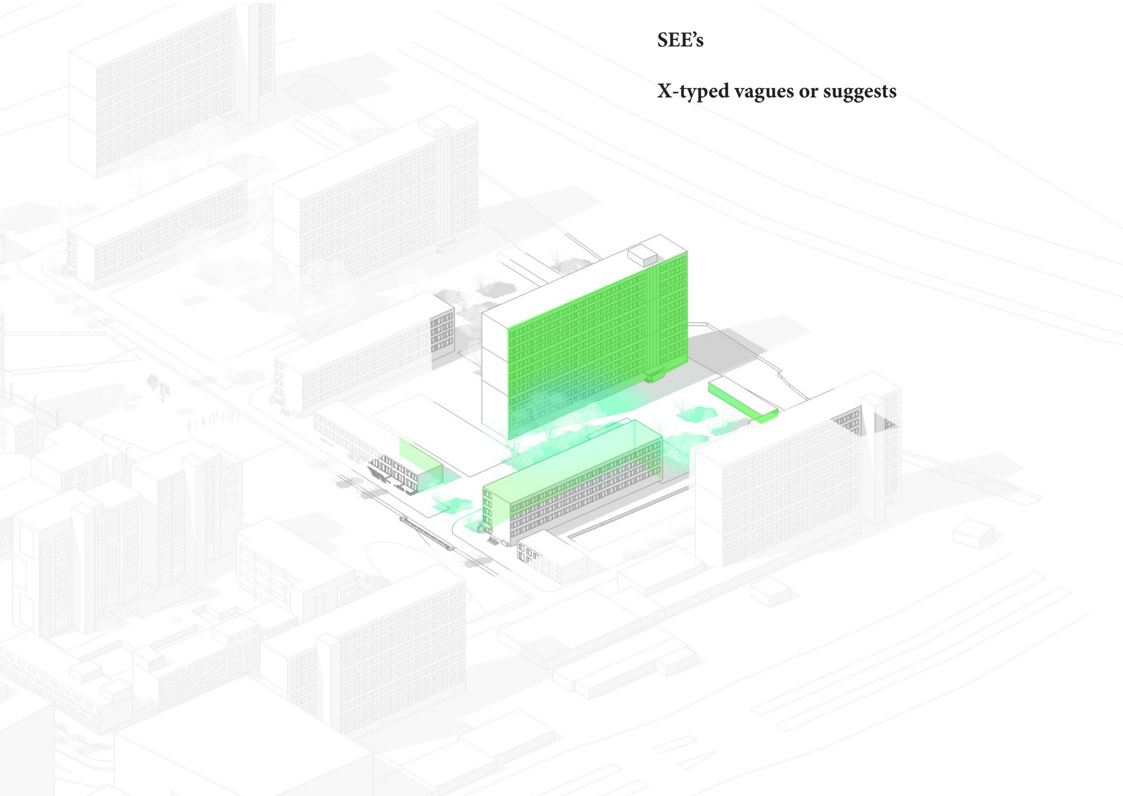




The general spatial structure of Westerkwartier is characterized by a grid of longitudinal corridors of narrow streets with two to three story buildings on both sides of the street. If we look at the spatial structure of Poptahof, we see a completely different picture: very open spaces that flow into each other. While the previous patterns gave a general description of the cases, the following analysis is based on Thiel's enviro-tectural approach, and decomposes the spaces into scenes to give an anatomical description of spatial elements.

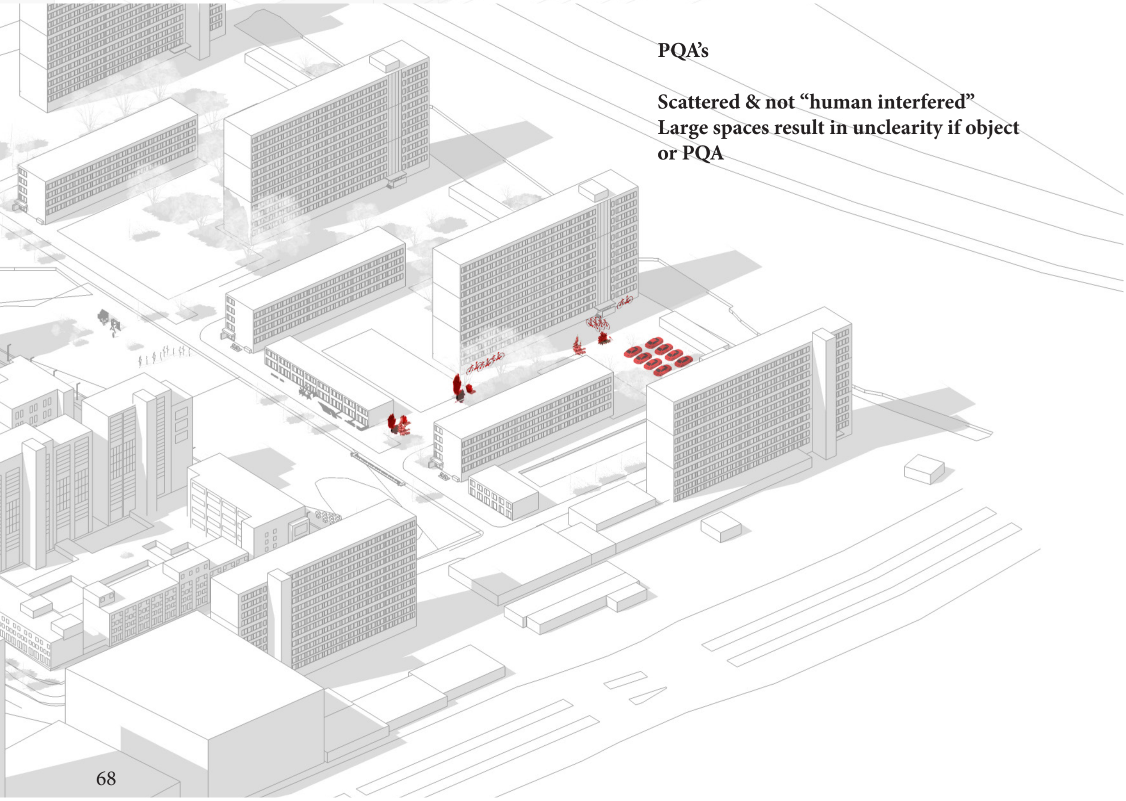
Primary and secondary spaces
As we walk outside, or in a building, we move through sequences of spaces. For this spatial analysis, it is important to distinguish those spaces we occupy at a given moment, and the spaces that we do not occupy, at the same moment. The definition of space occupancy here is a perceptual one and looks at space establishing elements (SEE's) that are visible across the UP its entire nominal visual field (180°). By highlighting SEE's we can get a more nuanced understanding of the composition and relation of primary and secondary spaces. Note that there is a difference between objects that establishes space, and objects that *furnish* the existing space.

Vagues, suggests, and volumes
By pointing out SEE's in our scenes, we are able to highlight the quality of the space: a vague area, a well-defined volumetric space, or a suggested space in-between. We can also directly see whether the space is a coherent, and symmetric 'O' type, or an irregular, asymmetric, and romantic 'X' type.



SEE's

X-typed vagues or suggests

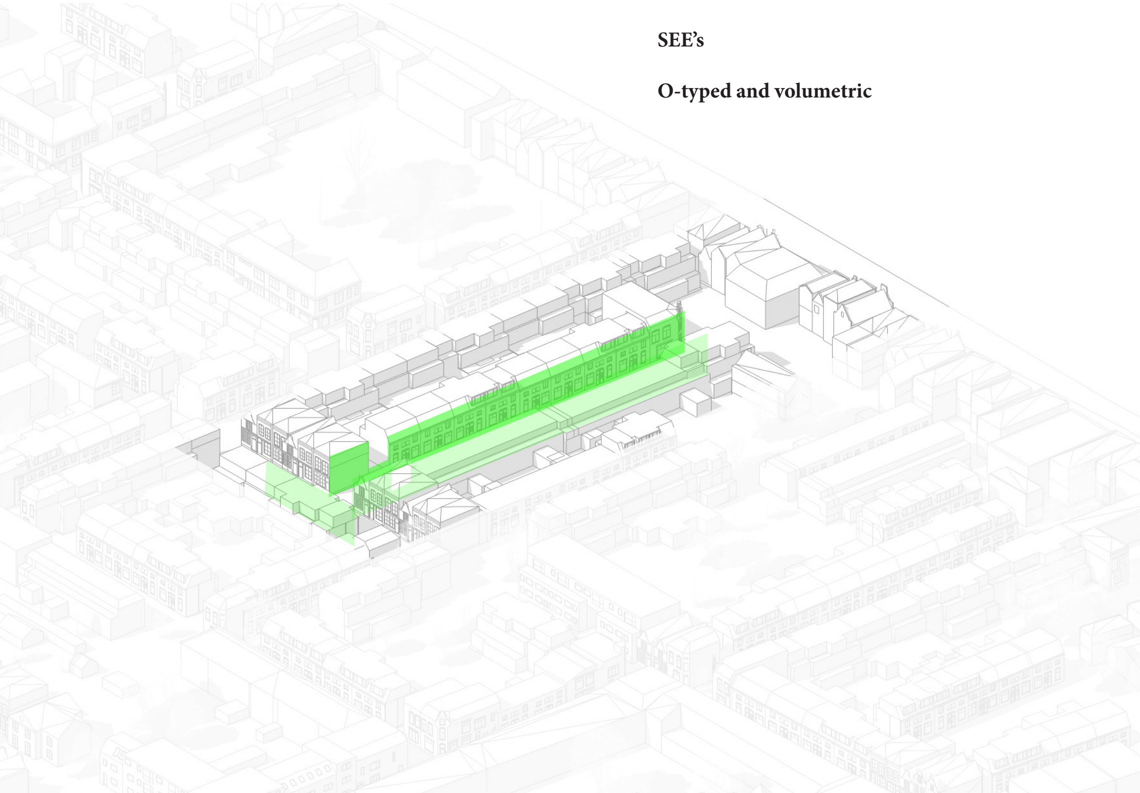


PQA's

Scattered & not "human interfered"
Large spaces result in unclearity if object or PQA

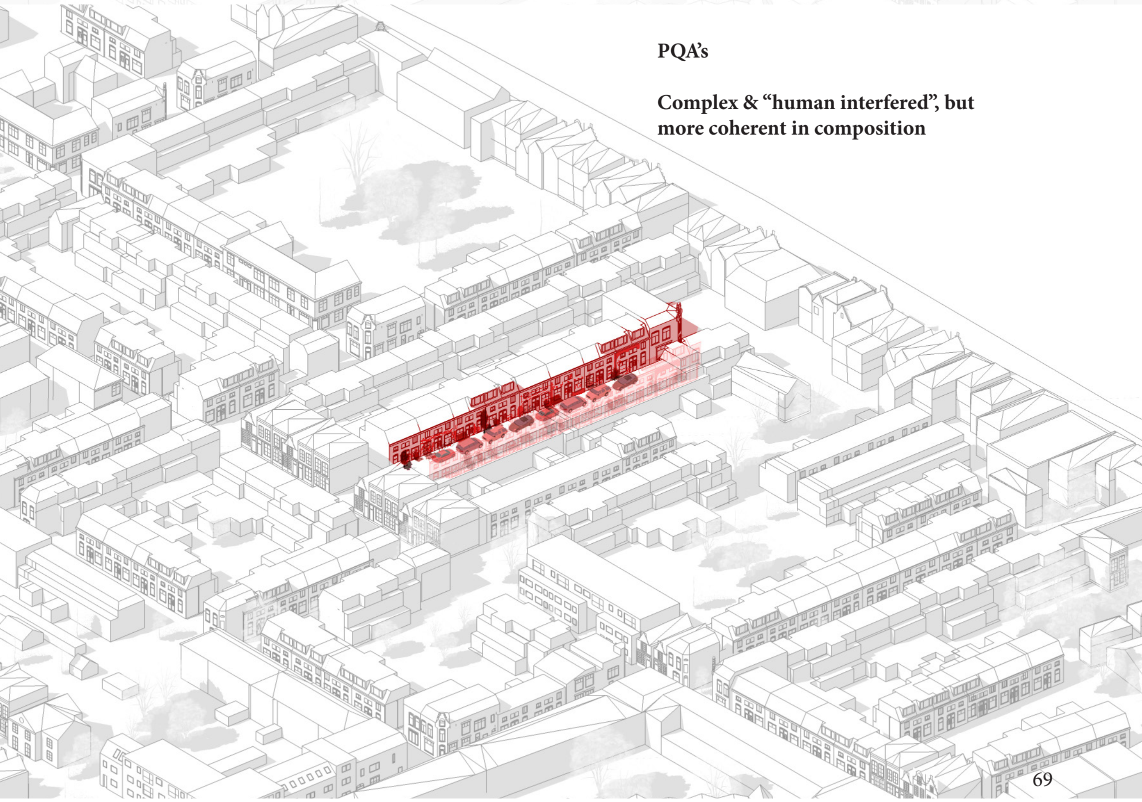
SEE's

O-typed and volumetric



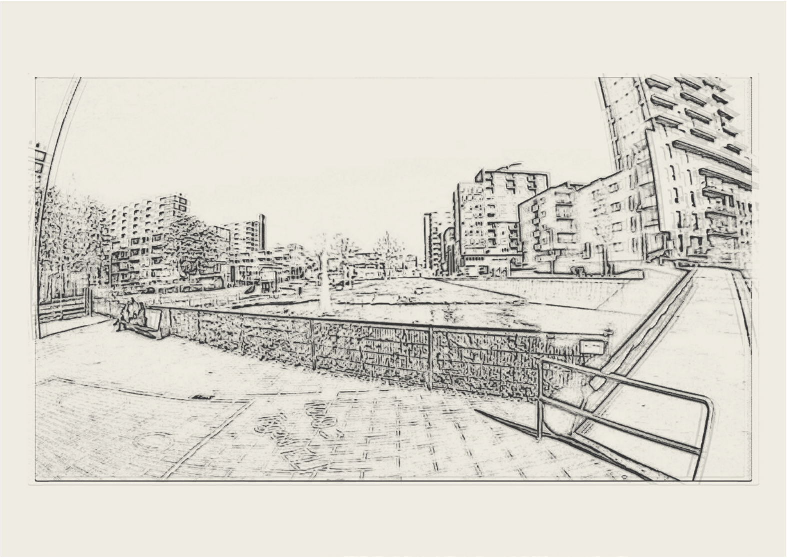
PQA's

Complex & "human interfered", but more coherent in composition



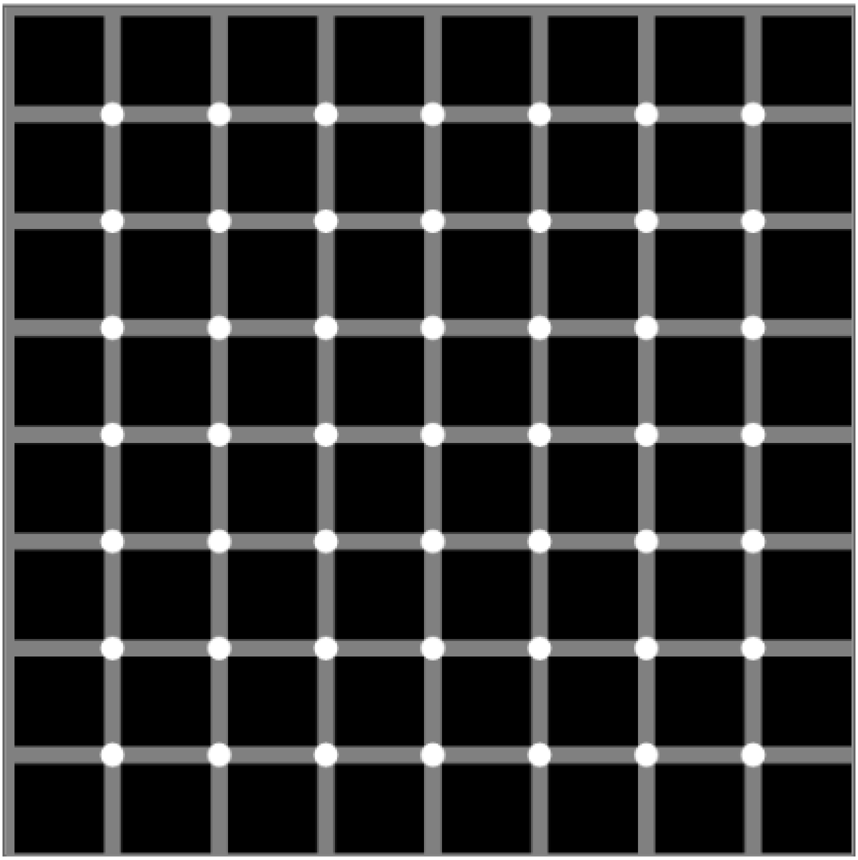
Several descriptive imagery studies and psychological research on the visual perception of (urban) environments e.g. (Cullen, 1971; Lynch & Rivkin, 1959; Prak, 1979; Kaplan & Kaplan, 1989) emphasize the importance of coherence and complexity of visual information in the visual field, or that of images. If we look at the scenes from the eye-level, and simplify the visual field in sketch-like images, we can hypothetically highlight which elements are expected to be perceived in terms of the elements their complexity, coherence, contrast, and gestalt.

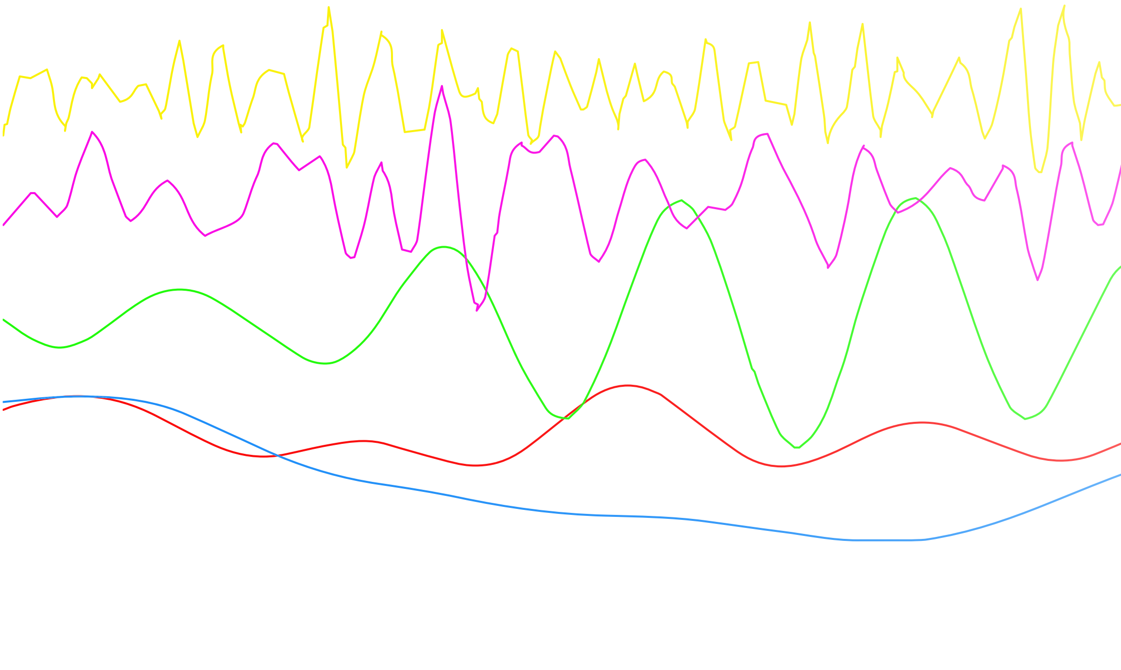
Scenes in Westerkwartier are spatially more coherent, with very complex and personalized objects, or as Thiel refers to, humanly interfered PQA's along the façades. Vistas with a clear vanishing point are present. Elements such as window frames, doors or rain pipes create rhythmic patterns, while corners of buildings, slim trees, blind façades, overhangs or dormers create certain datum.



With the exception of the sequence in the courtyard, scenes in Poptahof are generally defined by X-shaped spaces with vagues. According to Prak, it is impossible to create internal representations of space within these kinds of scenes. Spaces lack foreclosure and create dispersed and messy visual arrays. However, the sequence with a clear view of the park creates a *serial view* (Cullen, 1971), which emphasizes the SEE surface on the UNDER- side, ultimately creating a more coherent picture.

PART II





5. METHODOLOGY

This explorative research uses consumer-grade mobile electroencephalogram (EEG), and eye-tracking technology to calibrate measured brain activity with attended stimuli in urban scenes. This way, the goal is to bridge the disciplines of urban design, environmental psychology, psychophysics, and psychophysiology. With this novel approach, we can create a base for empirical research on the perception of landscapes and urban scenes. The methodology uses *quantitative* measurements, commonly used in object perception research, and applies it in environmental perception research. *Qualitative* methods in the form of semi-structured interviews with the subject will address cognitive and appraisal phenomena, which are not quantifiable with technological tools within the scope of this research. Ex-ante interviews will address the cognitive bias, or pre-attended cognition. Interviews ex-post will address remembered feelings or emotions to define subtle appraisals. The initial part of this research explores possibilities and limits of available methods.

Units

Research units, of whom the data are measured, are persons (adults) that are not familiar with the area. Two persons were willing to participate in test-runs, and eventually five persons have participated in the actual measurements. Because the dimension and sensitivity of the devices, and because the measurements involve patience and stable positioning, unfortunately, children were not able to participate.

Case selection

As is defined in chapter three, the case and test route are selected based on a set of criteria:

- Architectural ensemble (time/era, architectural style, and relative positioning to the city centre)
- Physical space (SEE's, PQA's and MH's)
- Presence of design principles ((symmetrical) axis, hierarchy, contrast, rhythm, datum, complexity, and transformation) and the compositional link between.
- Presence of a clear pattern language (#patterns stated in ch.4)
- Variety in axis, hierarchy, contrast, rhythm/ repetition, datum, complexity, and transformation
- Practicalities, such as: Low traffic interference, short walking distances, and available pool of subjects willing to participate in research.

Pilot case

The pilot case is selected based on the criteria given above and is located in Poptahof (Delft). It comprises a range of different urban scenes and spaces within a walkable distance. To avoid any misinterpretation of patterns, relations, or causalities, the route will be travelled from A-B and B-A.

Cases

After the initial tests in the pilot case, the case of Westerkwartier (Delft), with different environmental settings was added.

The setting:
architectural ensemble (ind)
physical space (ind)
design principles (ind)
pattern language (ind)

micro climate (ext)
traffic flow (ext)

socio-physical aspects (ind)
socio-spatial aspacts (ind)

presumed livability (ind)
perceived livability (dep)

visual affordances (dep)
image elements (dep)

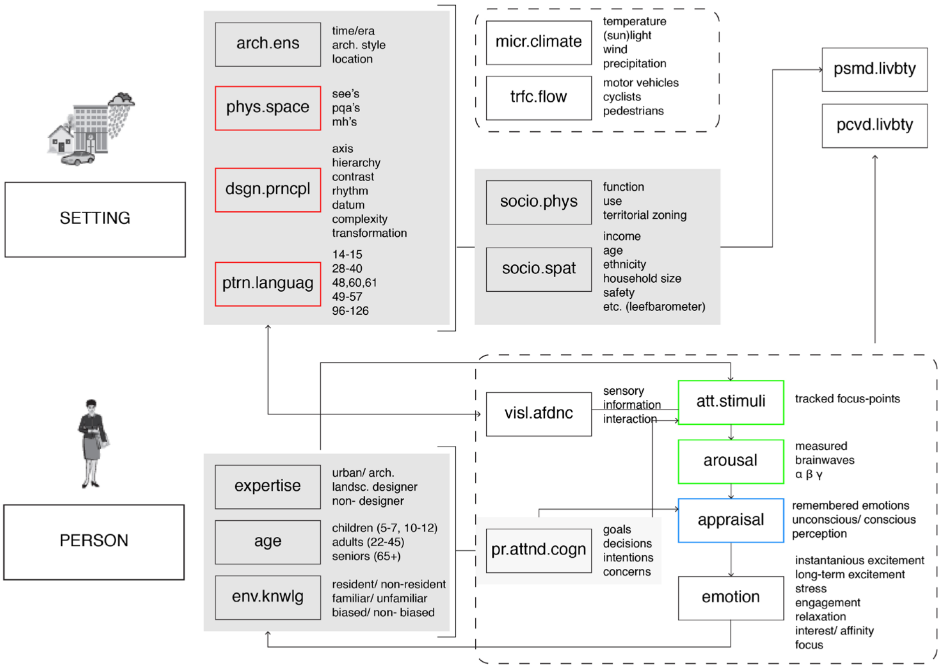
The Person
expertise (dep)
age (ind)
environmental cognition (dep)

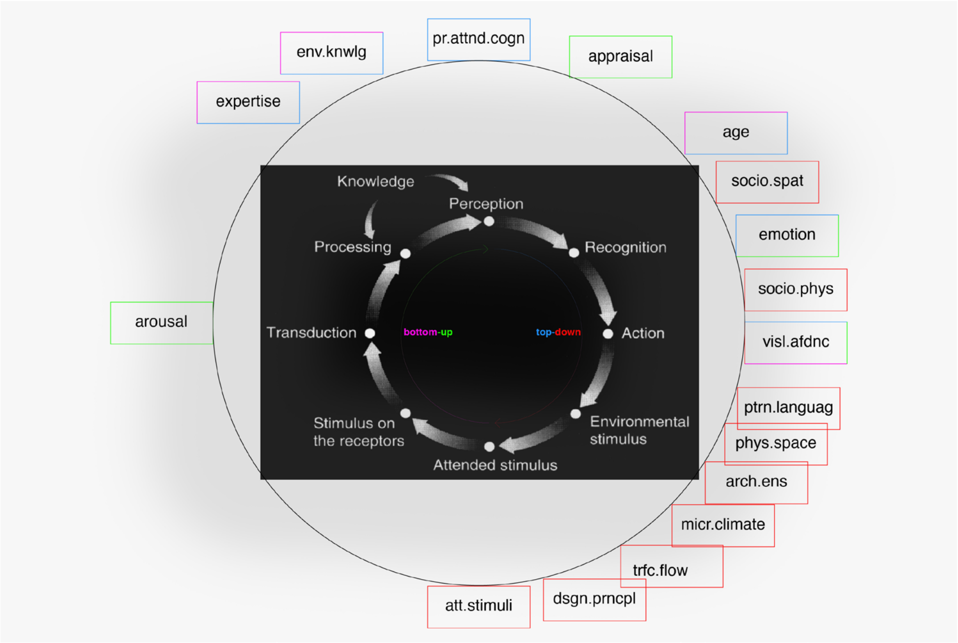
pre attended cognition (dep)

attended stimuli (dep)
appraisal (dep)

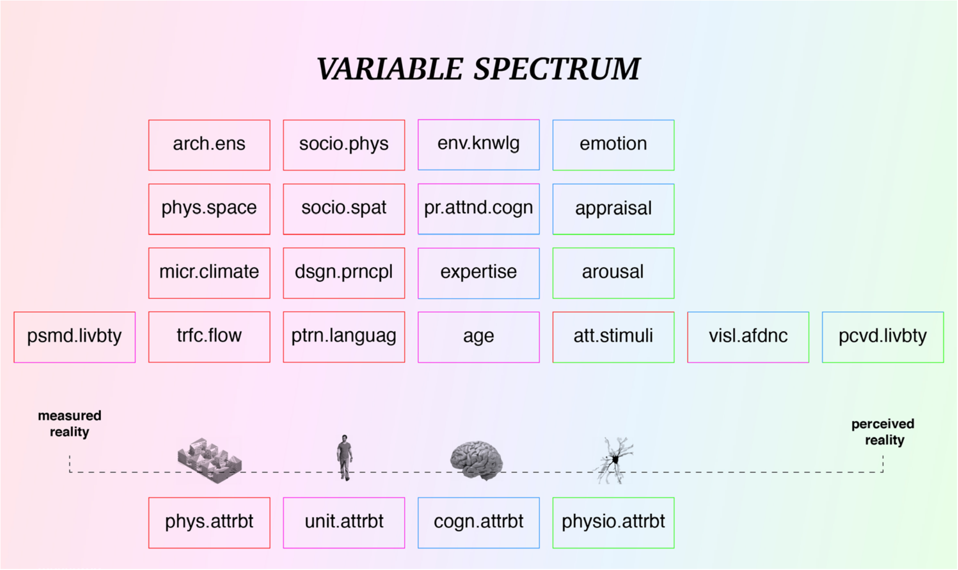
Relation variables (author)

The research focuses on the relation between physical space, design (ordering) principles the present pattern language, the attended stimuli, EEG arousal (alertness) and appraisal. The aim is to achieve input for the broader term of perceived livability (van Dorst, 2005).

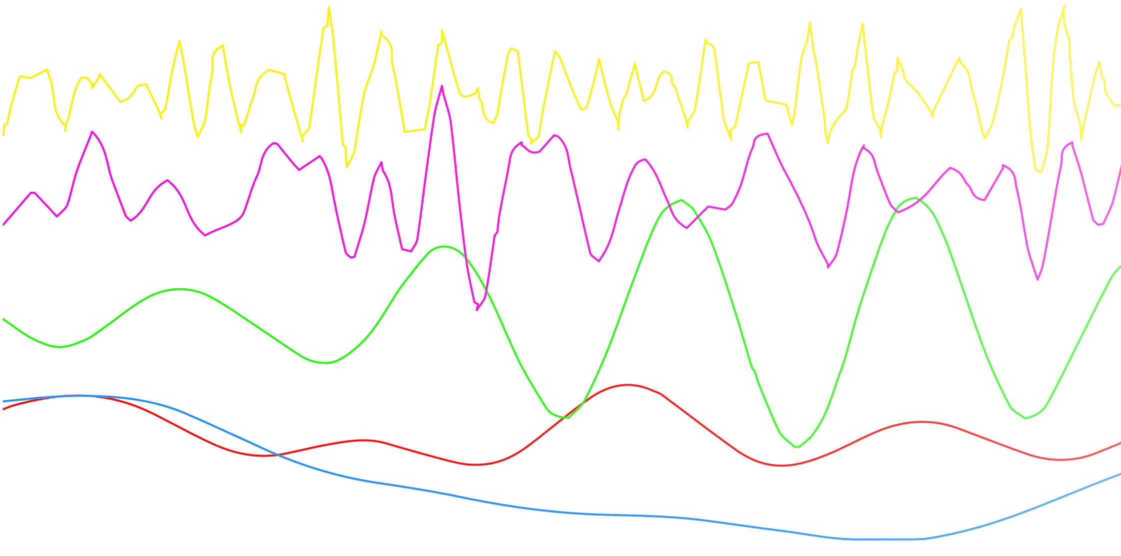




env.knwlg
pr.attnd.cogn
appraisal
expertise
age
socio.spat
emotion
socio.phys
visl.afdnc
arousal
ptrn.languag
phys.space
arch.ens
micr.climate
trfc.flow
dsgn.prncpl
att.stimuli
Knowledge
Perception
Processing
Recognition
Transduction
bottom-up
top-down
Action
Stimulus on
the receptors
Environmental
stimulus
Attended stimulus



VARIABLE SPECTRUM
arch.ens
socio.phys
env.knwlg
emotion
phys.space
socio.spat
pr.attnd.cogn
appraisal
micr.climate
dsgn.prncpl
expertise
arousal
psmd.livbty
trfc.flow
ptrn.languag
age
att.stimuli
visl.afdnc
pcvd.livbty
measured
reality
perceived
reality
phys.attrbt
unit.attrbt
cogn.attrbt
physio.attrbt



6. EXPLORING METHODS

Methodology & practice

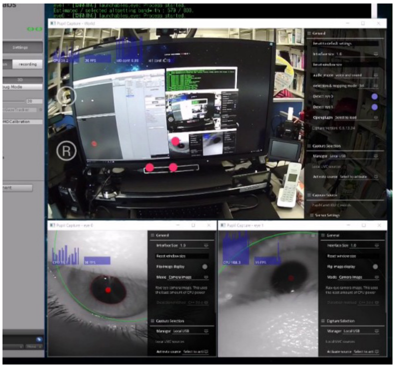
The initial part of this research is explorative of nature and aims to address methodological and practical issues to ensure a functional workflow. The very first test-runs are aimed to get familiar with the equipment and to test the possibilities to use these commercially available “wearables” for urban design research purposes. The following sections include short descriptions of the devices, followed by the used methods and found results.

Pupil-labs eye tracker:

This wearable headset lets you record and monitor where people actually focus their visions on. The 3D printed frame holds a 'world camera' that records the participant its viewing direction, and a smaller infrared camera pointed towards the eye that records pupil movements. The device is connected and powered via USB. After calibrating the two cameras, the software lets you monitor and record the participant's gaze points. After the recording, it is optional to render the eye-tracked video with a variety of representation settings and gaze time thresholds. For image stills, it is also possible to analyze gaze positions on fixed surfaces to create heat-maps.

Pupil-Labs® mobile eye-tracker

The field of vision (FOV) camera, that comes with a 60 deg. and 100 deg. diagonal interchangeable lens, runs at resolutions 1920x1080 @30fps, 1280x720 @60fps, 640x480 @120fps, with a latency of 5.7ms. The 120 fps eye camera runs at a resolution of 640x480 with a latency of 5.7ms.



Pupil-Labs Capture software interface

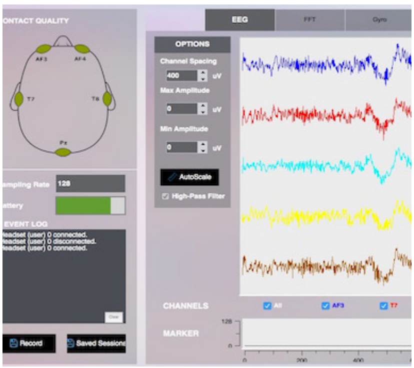
Pupil-labs has its own open-source platform on GitHub, which provides additional tools to code and create personalized software, depending on what the research goals are. For this research the Pupil-labs its standard software 'Capture' is used to monitor, record, and render videos.

Emotiv Insight EEG headset:

Emotiv Insight® 5 Channel Wireless EEG Headset

The 'Emotiv Insight' is a mobile EEG device that records the participant's brainwaves through five electrode sensors that are put on the scalp. As is shown in the "understanding EEG" section, the positions of the electrodes are determined by- and based on the IFCN combinatorial electrode nomenclature its "10-5" positioning system. The electrodes capture signals in the frontal lobes (Af3 & Af4), temporal lobes (T7 & T8), and parietal lobe (Pz). Furthermore, nine axis motion sensors capture head position and movement.

The transmission rate of each sensor is 128 samples per second with a minimum voltage resolution of 0.51 μV. The sensors respond to frequencies between 1 to 43Hz. The device uses a Bluetooth connection and a lithium powered battery that lasts four hours.



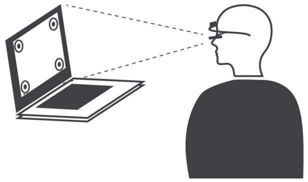
Emotiv Pure EEG software interface

The Emotiv 'Pure EEG' software interface lets the operator monitor the connection quality of each electrode and record brainwave activity in the form of a real-time frequency-amplitude graph. In the initial phase of the research, experiments are done with solely using the manufacturer its software. In later analyses recorded sessions are exported to analyze the data more accurately.

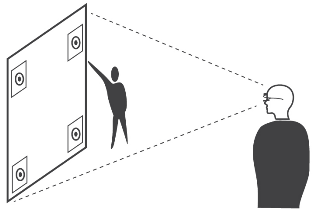
Methodology & practice: testing the equipment and software

Eye-tracking calibration

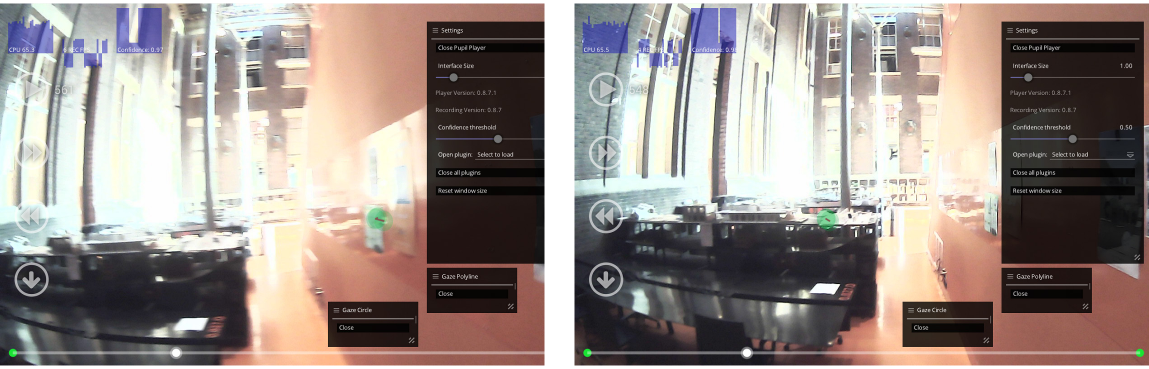
For practical reasons the very first tests were held inside. For the use of the eye-tracker, experimenting with different calibration methods and different gaze distances gave useful insight on how to cope with 'parallax'. Parallax is the phenomenon that appears when an object is viewed from different sightlines (e.g. when the fuel indicator needle of a car seems emptier when viewed from the passenger seat). The difference of the apparent position of an object vs. its background is much greater for objects that are closer to the eye. Because this version of the eye-tracker is monocular (i.e. tracks one eye), the calibration method is crucial for getting optimal results. The on-screen calibration method is useful for tracking objects in a room, while larger distances require manual calibration with the use of printed markers.



On-screen calibration

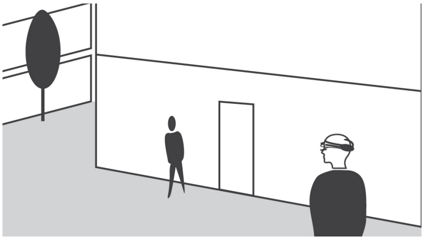


Manual calibration using printed targets



Testing calibration & parallax-error results in the Orange hall

EEG Sensor connection
For the EEG headset it takes a while to get all the sensors to make good contact with the scalp (especially when the participant has thicker hair). Applying a solution of salt water to the parts of the scalp that make contact with the sensors however, improves conductivity and contact quality. While the software allows you to record, monitor and play back brainwave activity, it is much harder to analyze the EEG data accurately with the standard manufacturer's software. For the analysis, as is explained later on, an external MatLab plugin, EEGlab is used which allows you to scroll through, close-read EEG data, and run event-related spectral perturbation (ERSP) analyses.



Method 1: Field runs

Method 1: 'field runs'

The first test-runs in the field were held in Poptahof, Delft. After calibrating the eye-tracker and setting up the EEG device, we started walking the case-study route in the area. Soon it became clear that the weather condition is a decisive factor for the tests to become useful and give results. The field test-runs results are summed up below:

1. Direct sunlight & overexposure: The infrared camera of the eye-tracker is sensitive on sunny days. With direct heavy sunlight, the eye-tracker has difficulties detecting the pupil, even after adjusting the camera settings. This is caused by camera overexposure and due to subject its pinching of the eyelids, (especially when the subject has mascara on the eyelashes). Solution: Do runs on cloudy days, or during the sunset gap when there is less exposure to direct sunlight.

2. Rain and wind: The devices are primarily designed for indoor use. It is therefore obvious that the runs cannot be done while it is raining. Heavy wind gusts can also distort the positioning of the headsets and the subject its perception.
Solution: Do runs on clear days.

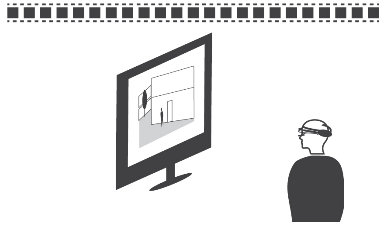
3. Head motion and FOV influence: Because the devices are portable, the subject can look freely around the real world, however the eye-tracker uses a USB cable connection with the recording hardware (in this case a laptop computer). Walking next to the subject has its perks of influencing the FOV.
Solution: Walk slightly behind subject. Preferable to record the runs with a powerful tablet computer.

4. Hardware specifications: Running both eye-tracking and EEG software requires a decent CPU and enough RAM on the recording device. A solid-state drive is preferable for eliminating errors due to movement shocks.
Solution: Use powerful hardware.

5. Retinal image stabilization: The process of image stabilization in the brain, i.e. vestibulo-ocular reflex, occurs when the inner ear (vestibular system) automatically compensates for the movement of the body and the retinal image. The positive side of this occurrence is that it does not affect the tracked gaze positions.

6. Locomotion, scanning, and motor function: A disadvantage of the field-run is that the subject is in constant motion. This shows in the activity of the primary motor cortex area of the brain (represented by sensors T8 & Pz). The downside however is that the Pz area (parietel lobe) is also linked to the integration of sensory information, including spatial sense, navigation and (via the occipital lobe) the visual system. The T8 sensor captures brainwaves that are located in the temporal lobe, which is known for processing sensory input into derived meanings through (short) visual memories and emotion association. The constant high activity of Pz and T8 thus makes it impossible to neutralize brainwaves that occur by locomotion and solely analyze the activity of visual perception and emotional evaluation. The Emotiv EEG device is extremely sensitive to motion and therefore makes probability analyses of detailed spatial elements rather difficult. Although the device is previously used in broader environmental studies such as the effect of green parks and traffic congestion to sensory stimulation (Mavros et al, 2016), more detailed analyses of cause-effect probabilities between spatial elements and brainwave patterns are unlikely to be distinguished.
Solution: No solution for field runs

To summarize:
Tracking gaze positions in the field proved to be a difficult task that is heavily dependent on perfect weather conditions. In order to achieve useful results, one has to perfectly time the run on cloudy days with no rain and minimal wind. With perfect weather conditions however, the subject has a free range of motion of the head. This way the field of view and the visual perception is influenced by real-time environmental conditions (the relation between setting, decisions and behavior in Gifford's model).



Method 2: 'video tracking'

In order to eliminate the weather problem during field runs, a second more practical method is used with pre-recorded videos of routes in both cases. The recorded video is shown to the subject in a familiar setting (living room of the subject) while tracking gaze and brainwave activity. Although it is more practical in terms of time and use, this method leans towards the traditional perception research in a controlled environment. This however eliminates the external "setting" factors that heavily influence our perceptions in real-life and focuses on visual perception.

Apart from this shift from environmental perception towards visual perception, a very important distinction should be made between the field-runs and video tracking concerning what Gibson calls the "visual world" versus the "visual field". Tracking gaze and brainwave activity in the video method not only eliminates the senses of sound, balance, smell, and touch; it also affects the "realness" of visual perception: Dynamic aspects of the visual world, such as depth perception, or the occurrence of optical flows when we move through spaces in time (locomotion), are diminished. The rate in which stationary objects appear to move as a function of their relative distance to the perceiver (motion parallax) is also experienced two-dimensionally on a screen, rather than the real–world physical perception of information of surfaces and objects that enter the retina and visual cortex. Nonetheless, the use of images for environmental perceptive research is a well-known method for e.g. the evaluation of different environmental scenes because the images *represent* the visual field and the information perceived on surfaces and objects. A research on environmental evaluation based on static vs. dynamic displays (Heft & Nasar, 2000) for instance, has shown that static images of scenes tend to have a higher level of curiosity (about what will happen next) and a higher evaluation rating than dynamic displays. This makes

sense because when looking at an image, the subject experiences a certain tension, with no following release, and above all, has more time to analyze the scene, looking for smaller details that give the scene its quality.
Although not perceiving the real physical environment c.q. moving in the “visual world”, where all senses are activated, and where the setting actually influences our behaviour and thus also our “visual field”, the results listed below show interesting similarities and practical differences when compared to the results with the field-run method.

1. Scanning surfaces and objects

When we walk outside, the visual world is ordinarily perceived by scanning, i.e. rapidly moving our eyes from point to point, fixating on surfaces and objects. Notice that these surfaces and objects are only clear and detailed when our eyes are fixated on them. The observer gets this fact from observing the *visual field*, and not the *visual world*. The same happens when we analyze the tracked gaze positions from the video method. When comparing the two methods with the same subjects, using the exact same video of the subject its field-run, the results show no drastic differences in terms of scanned surfaces and objects. There is however a slight increase in the observers’ scanning rate. On screen, subjects tend to scan the environment slightly faster than in real-life. Gaze points that are held for longer than a second however, tend to be the same.

2. Vestibulo-ocular reflex

As is mentioned before, this reflex is created when our eyes are fixated on a point while the rest of our body, including our head, is moving. In reality, this reflex creates a stabilized image, but because the actual world-camera footages of the field-runs are used (for comparing purposes), this had created shaky videos with noticeable footstep-shocks. While some participants were getting slightly annoyed (and in one case even lightly nauseous) by these “bumps”, it confirmed that the subjects are actually focusing on detailed points that are worth gazing for a longer time interval. In the tracked gaze positions, this has resulted in short vertical lines that follow the fixated points.

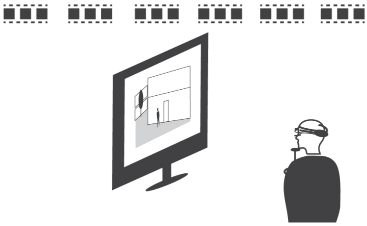
3. Frame-freeze

Another accidental and yet interesting discovery, adding to the findings of Heft & Nasar (2000), is the occurrence of a frame “freeze” of the video playback during the video track sessions. The accidental frame-freeze, which occurs occasionally due to a slow play-back response from the video medium resulted in split-second stills, where the observer gets to scan more surfaces and objects. This very quick scan is usually done by following a line on a surface, the edge of a shape, or an array of small objects.

4. EEG dynamics
The biggest advantage of this method is that the tests are done in a controlled environment with minimum movement of the body. The occurrence of constant activity in the motor system, the somatosensory system, and the auditory sensory system in the brain is kept to a minimum so the EEG peaks and frequency bands mainly represent visual stimuli.

5. Comparing validity
Another advantage of the video track method is that the footage, with the exception of occasionally frame freezes, is exactly the same. By keeping the footage exactly the same, and by keeping external influences to a minimum, this method validates the comparison of EEG data between multiple subjects.

6. Fake encounters
Next to depth perception, and the lack of visual flows and motion parallax, another disadvantage of this method is that encounters with people or other occasions are not real. This also shows in the EEG data when the subject encounters people face-to-face or a group of people. The increase in amplitude are more abundant in the field runs and last longer.



Method 3: Randomized scenes with chin rest

Method 3: 'Randomized scenes' with chin rest

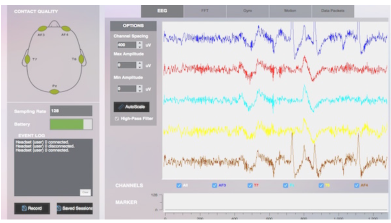
To continue this research and to compare and validate data, the video- method is adjusted by editing videos of the routes into smaller sections of footage. Similar to EEG research in laboratoria, a chin-rest is used to minimize body movements and to stabilize the participant's field of view.

1. Pre-attended cognition
By now the attended participants are familiar with the route and are thus biased by recognizable events. To minimize the influence of pre-attended cognition, the order of scenes is randomized. The scenes fade in and out with a margin of entering and exiting the scene. Doing this allows to measure activity between scene transitions, i.e. the movement from space A to space B.

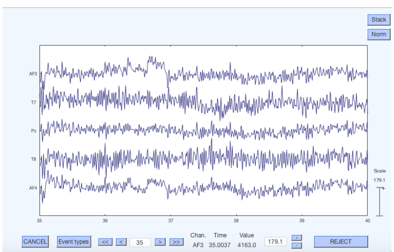
2. Validation by comparison
This short-clip method also allowed to compare events that occur in the video-runs of method 2 and to verify the cause-effect probabilities of tracked elements and the relation with brainwave activity.

3. Shaky video stabilization
One concerning disadvantage of the second method was that participants complained about dizziness due to shaky videos. The high-resolution camera that allowed to record footage at 60 frames per second produced very clear videos. The downside however was that no stabilizer was used during recording, which resulted in high definition shaky videos. The shocking walking motion was too present which caused a constant adjustment of the participant its focal point. This was clearly visible in the eye-tracking videos in the form of very short and squiggly lines, instead of fixed points. Nonetheless, it provided a stronger validity of the focus-points on certain spatial elements. However, for the comfort of the participants, the videos were stabilized using advanced stabilization software without distorting the footage.

Eye-tracking video of Westerkwartier



EMOTIV 'Xavier pure EEG' interface



EEG Lab's scroll function

Data analysis methods

Pupil Labs player

The real-time eye-tracking data can be played backed per frame in the Pupil Labs player and exported with desired plugins. For the purpose of this research, gaze circles and lines are rendered in the footage to track gaze positions with their trajectory of scanned paths.

Xavier pure EEG software

Emotiv its own developed software provides a clear user interface with an easy and fast access to collected datasets. While the program is useful for a quick and general analysis, it lacks the ability to run more detailed analyses.

MATLAB R2017 with EEGlab plugin

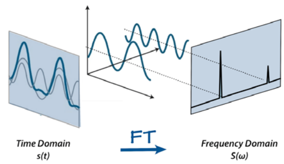
The EEGlab is a Matlab toolbox and is a common analysis tool in the field of EEG research. The toolbox allows to accurately scroll through the EEG dataset, run advanced time-frequency analyses, and plot data in numerous ways, including heat maps of the channels.

Time-frequency decompositions & Event-Related Spectral Perturbation (ERSP) analyses in EEG Lab

As we have seen in the “Understanding EEG” section, brainwaves are classified into certain bandwidths with associated mental states: δ (0.1Hz – 3Hz, in deep transcendental meditation), θ (4Hz – 7Hz, in a dream), α (8Hz – 15Hz, in quietly flowing thoughts), β (16Hz – 30Hz, in normal waking consciousness and heightened state of alertness), and γ (31Hz – 100Hz, in higher processing tasks and cognitive functioning). In practice, EEG signals consist of a mixture of complex frequencies that change rapidly over a short period of time. For interpreting the raw EEG data, it is thus essential to analyze the occurrence, clustering and fluctuation of frequencies within certain bandwidths (α, β, or γ) for the corresponding area of the brain. To do this, a *Fourier transform* is used to decompose complex frequencies into an alternate representation. In our case, the Fourier transform basically converts the function of time (t) into the function of frequency domains.

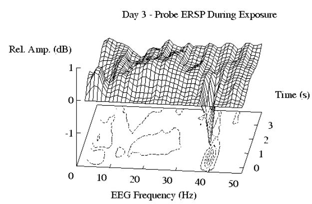
$$F(\omega) = \int_{-\infty}^{\infty} f(t) e^{-i\omega t} dt$$

$$f(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(\omega) e^{i\omega t} d\omega$$

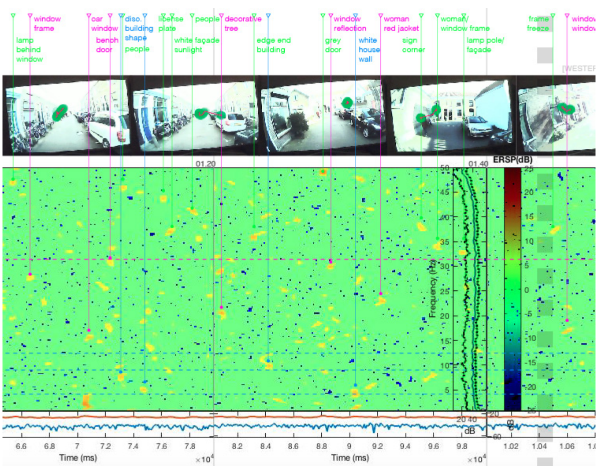


Fourier transform

The Event-Related Spectral Perturbation (ERSP) analysis is used to study event-related brain dynamics. This method adds a third dimension of time to the analysis. This way we can get a better understanding of the power spectrum (relative amplitude in dB) of certain EEG frequency bands (alpha, beta, and gamma) occur at a given time (ms). The figure below is from auditory evoked response experiments during a four-day study of the effects of 24-hour free-field exposure to intermittent trains of 89 dB low frequency tones (Makeig, 1993).



Event-related Spectral Perturbation (ERSP). (Makeig, 1993)



ERSP analysis (author)

Brief semi-structured interviews

While the eye-tracker determines which spatial elements are perceived at a given moment in time, and the mobile EEG sensor measures brainwave dynamics, data for variables related to appraisal are collected through semi-structured interviews with the participants after the eye-tracking, and EEG data is analyzed. The significant events (in the ERSP analyses) are then selected and pointed out in the eye-tracked video to the participant in order to recollect a more detailed description of what is perceived, and how the spatial elements are appraised. Pointing out tracked gaze points with interviews ex-post, addresses short-term memories (associated with EEG channel coherence of Pz and T8) to define subtle appraisals based on the preference model (Kaplan & Kaplan, 1989).

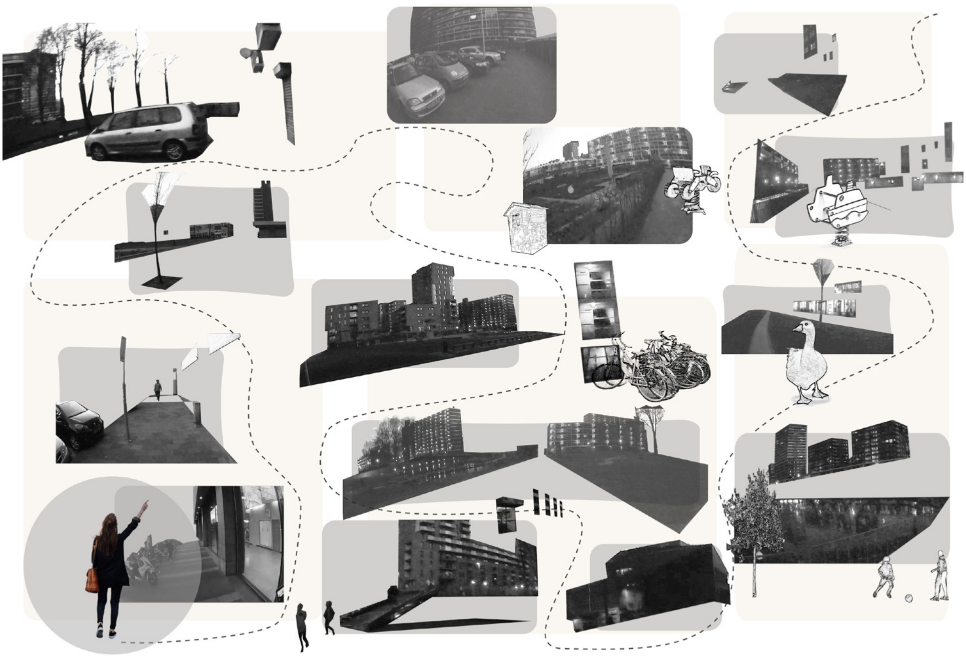
General:
Which area do you think is a better neighbourhood?
What did you like best about the area?

Scenes (per case):
Which parts (of the footage) did you think were attractive?
Why did you like theses parts in particular?
Which parts (of the footage) did you think were least attractive?
Why did you dislike these parts in particular?

Events (based on gaze positions or scan trajectory
Here [time frame] you looked at [tracked elements]. Can you describe what you were thinking or how you felt about it?

Results

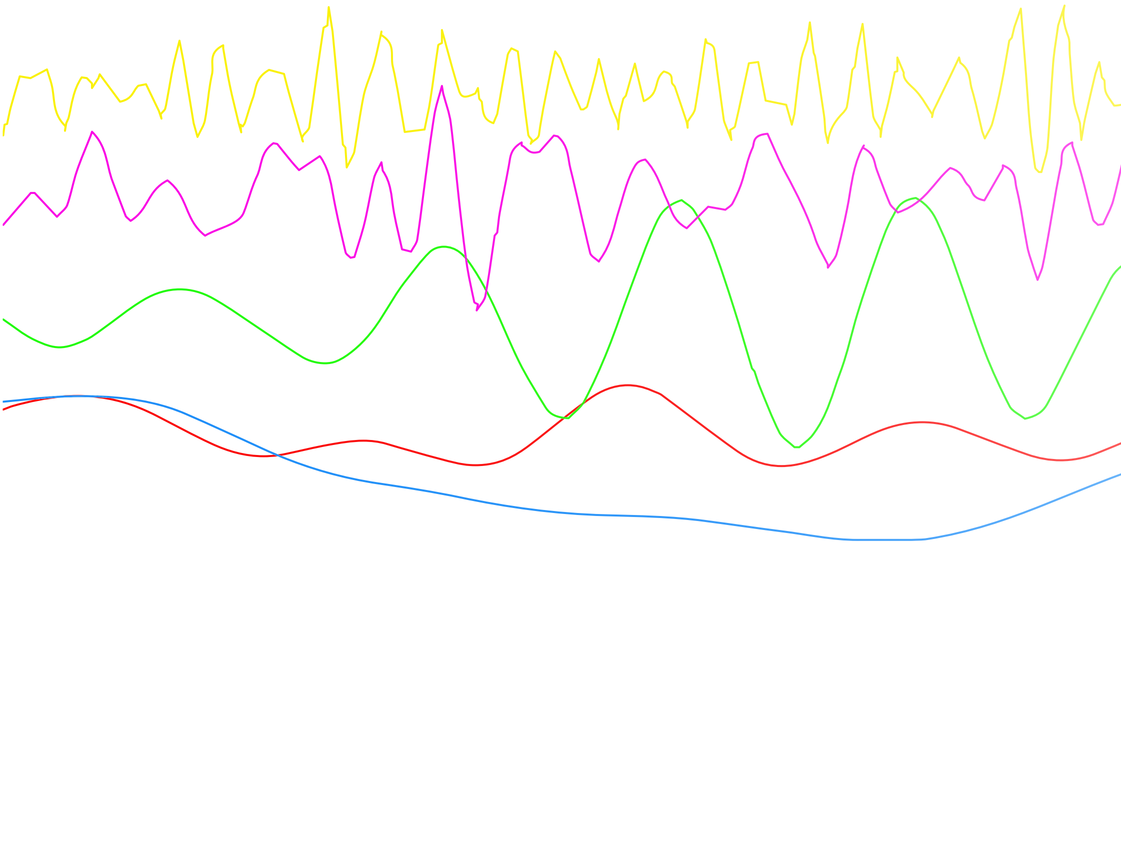
[M1]
As is mentioned previously, the standard Emotiv 'Pure EEG' software lets you record and analyze real-time EEG data. With the first test-runs in Poptahof (method 1) the manufacturer its software was used in order to compare general fluctuations in amplitude and frequency bands within differently perceived primary spaces of the walking route. By conducting semi-structured interviews retrospectively with the eye-tracking video and EEG data at hand, we could trace back the participants their appraisal of different spaces. Mind-maps are made based upon the participants their answers. The interview questions are based on apparent events in the EEG data, i.e. sudden changes in frequency bands and their amplitude. By looking at the same time interval of the video in which EEG events occurred, certain spatial scenes could be referred to in the interview. This method



Mindmap example (author)

was useful for backing qualitative appraisals of certain spatial elements such as: disliking garbage on the street, obstructing parking meters, beautiful row of trees in front of buildings, unpleasantly large parking area, etc. Although being a great supportive tool for the eye-tracking data and qualitative interview method, the standard software does not provide an extensive tool for analysis. EEG dynamics mostly represent changing scenes (moving from space A to space B) and not specific spatial elements. The result thus heavily rely on qualitative semi-structured interviews. [plaatjes eerste runs]

[M2, M3]
The greatest advantage of the video-tracking method is that all participants see the same footage, which makes replicability and comparability possible for a more consistent and systematical analysis. The disadvantage however is that the research objective changes from the real-world setting to a two-dimensional screen, which eliminates setting measurements in reality, as is described in the previous chapter. By cutting the footage into separate scenes and stabilizing the footage, a more appropriate workflow is created. Randomizing the scene sequence also partly eliminated pre-attended cognition of participants who had already participated in the second method.



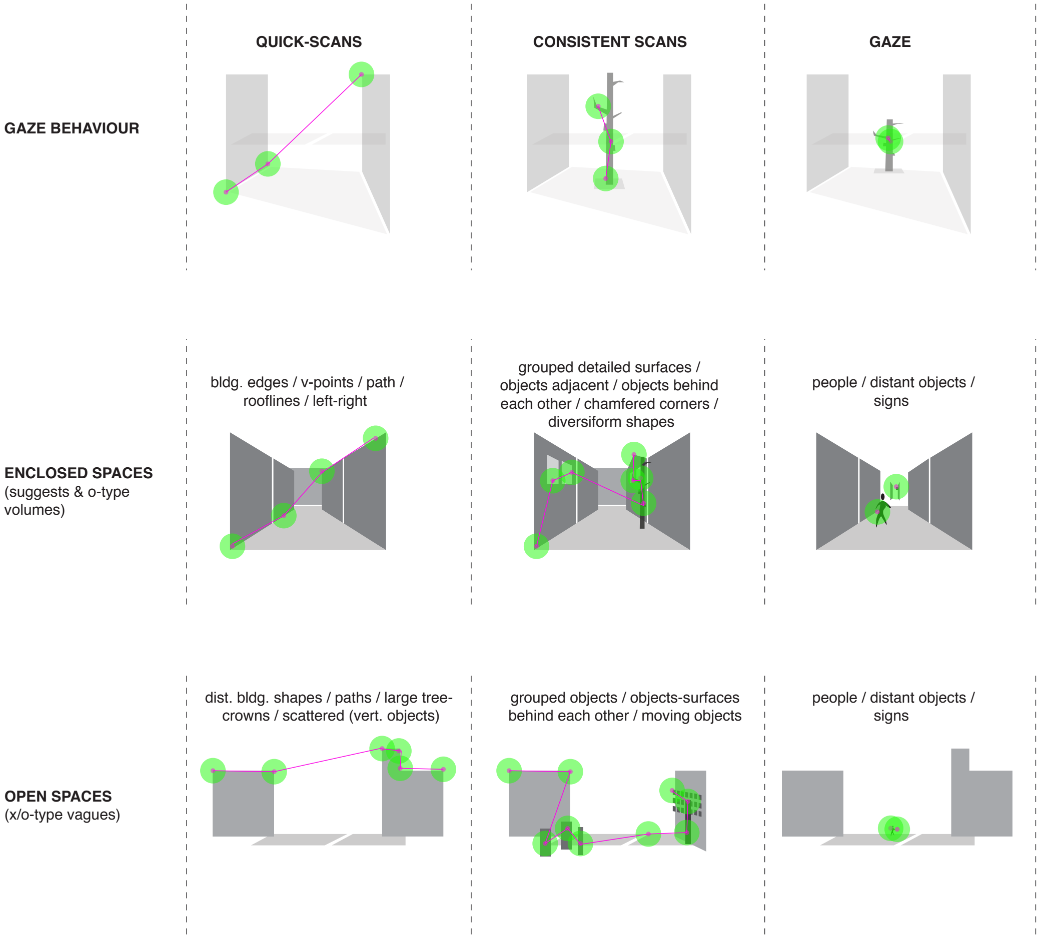
7. ERSP-VIDEO ANALYSIS

From the analysis, several general occurrences appear in relation to quick-scans, consistent scans, longer gaze positions (>0.5s), concentration in EEG frequency bands, and the Pz – T8 EEG channel coherence:

General occurrences

Quick-scans appear as short and rapidly changing points that leave a long gaze trail. They mostly occur when entering a scene where the space is open (X-shaped, or O-shaped vagues) where surfaces and objects are scattered around the visual array. Quick-scanning these open spaces, the stopping points that are scanned are on slim vertical elements, that appear closer to the participant than the background, such as trees or lamp posts. In closed suggests, or volumes with a clear vanishing point, these quick-scans appear more consistently, scanning along the joint edges of buildings (building shapes) or, along edges of the walking path surface (the edge of distinct pavement surface or texture, trottoir bands, building plinths, or a line of parked cars). In the ERSP's these quick scans appear in lower frequency bands. On the other hand, when the field of view abruptly moves in a horizontally panning motion, and when the participant tries to focus on multiple objects within a fracture of a second, while not being able to make something out of the situation, this results in a burst in the higher frequency range.

The peaks of frequency bands in the ERSP's also relate to the duration of gaze points, and the description of the participants: Concentrations in the alpha range are related to scanning the environment without actively observing or paying attention to elements, and as is mentioned before, to rapidly changing gaze points. Concentrations in the beta range however involve a higher form of (re-)cognition and occur when observing: *façade units* such as decorative pilasters, window frames, ornaments, rain-pipes or door frames; *objects* such as tree trunks, (lamp)-posts, signs, or parking meters; objects that refer to *social traces* such as benches, planters, climbing-plants, trash-bins or (groups of) bicycles; discontinuing *building shapes* such as chamfered buildings, terraces, blind façades, or roof dormers. Higher frequency ranges occur while focusing and gazing on distant or complex elements that require higher cognitive processing efforts, i.e. trying to make something out of what is perceived. These occur at distant objects, reflections on windows, encountering humans, looking at moving cars or cyclists and reading text on signs.



Gaze - space relation (author)

Gaze behaviour

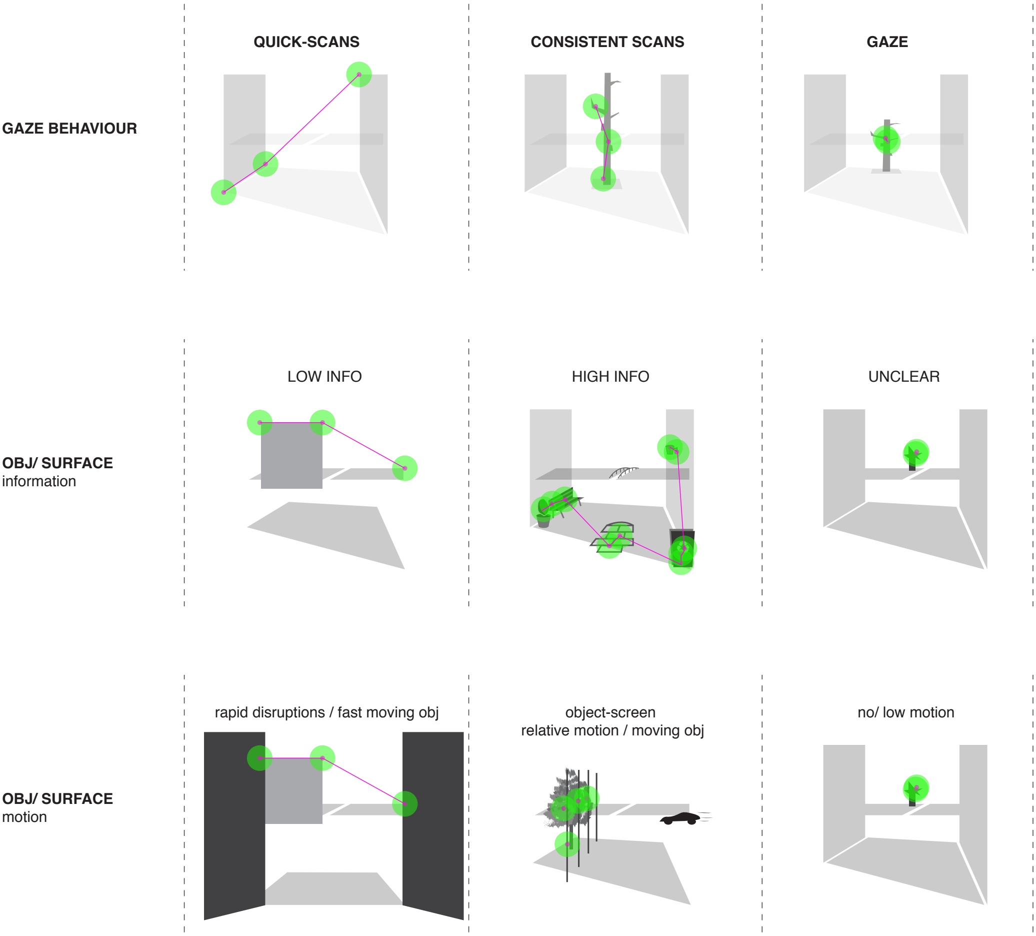
Eye movements of participants occur in three different observed speeds of quick-scanning (t <0,1s), scanning (0,1s < t < 0,5s), and gazing (t >0.5s). The eye movement speed and behaviour differs per sequence and is influenced by: [1] the panning movement of the visual array, [2] the amount of occasions in the form of moving persons or traffic, [3] the parallax effect and speed of optical flow of perceived objects in relation to their background [4] the spatial form quality, defined by space type (X-types, O-types or in-between) and explicitness defined by vagues, suggests, or volumes, [5] the perception of place-quality agents in relation to space-establishing elements, [6] the rate of complexity or coherence of SEE's and PQA's attributes and composition, and [7] the occurrence of vistas and that provide serial vision in the visual array.

Quick-scanning mostly occurs at larger open vagues and suggests, where space-establishing elements in the *side* (or front) position are distant to the perceiver. In these situations a substantial proportion of the field of view consists of surfaces in the *under* position that define paths, thus making vertical spatial elements stand out. Quick-scanning these type of spaces occur along horizontally defined lines or edges of horizontally defined surfaces and result in very short stops at vertical shaped objects or surfaces. In X-shaped suggests, the visual array consists of an even more complex set or composition of stimuli in the form of SEE's or PQA's, which results in a fast scanning motion of the visual array, where the gaze positions jolt from one set of SEE's or PQA's to another. Naturally, other reoccurring quick-scanning motions appear when sudden occasions appear in the form of fast moving cars, cyclists, or people, distracting the scan-path which then moves back-and forth between the attended SEE or PQA and occasion.

Quick-scanning vertical linear elements, scanning linear-shaped joint edges, and gazing at diversiform elements of interest

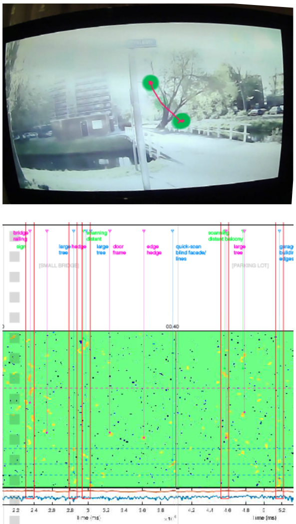
Scanning motions appear more consistently, with a shorter gaze trail, and move along joint edges of linear shaped surfaces or objects that are positioned adjacent or right behind each other. When the space is defined by a closed volumetric space type (O-type), or the frame of the visual array is defined by a visual vista (sometimes incidentally formed by temporary objects), the scanning motion occurs along the edges of the surfaces that form the vista. In less explicit spaces, vagues, or suggests, when the visual array lacks depth perception, or when the perceived surface is at a close distance, and affords little visual stimulation (e.g.

when viewing a flat façade orthogonally at a close distance), scans occur more scattered, following lines and edges, until the line is interrupted by another linear element or object, or when the participant blinks and starts at new position. However, when surfaces or objects do offer higher stimulus information in hierarchy, contrast, or complexity, the scan moves to that position in the visual array and focuses a longer period of time, which is referred to as gaze.
When perceived at a relative close distance, gazing reoccurs at surfaces, screens, and objects that are more complex or diversiform than the rest of the visual array. These elements afford the most set of (interactive) visual information, and occur as (smaller SEE's in relation to the space itself such as) bright, textured, and contrasting surfaces, (mesh or opaque) screens that provide a glimpse through them, or vertical objects that stand out. Even more common is gazing at PQA's that furnish the space, such as wall art, façade ornaments, bicycles, benches, planters, signs, window reflections or smaller and brighter trees. Gazing also occurs when focusing at distant objects, or a set of objects that form more complex and unclear shapes. In these occasions participants acknowledge the vagueness of the elements.



Gaze - object/surface relation (author)

Apart from the general results there are findings that are specific to the spatial context of the cases (as is described in the spatial analysis chapter). The section below describes space-establishing elements, place-quality agents, or occasions per scene, that show reoccurring patterns in the ERSP analyses, Pz – T8 channel coherences, and gaze behaviour.



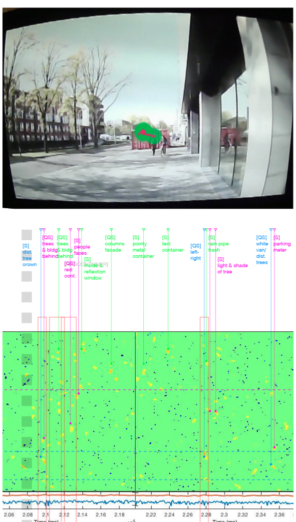
S1- Scanning tree, bridge railings, path

Poptahof – scene 1

[S] lamp-post, sign, and slanted tree positioned behind each other
[S] bridge railings & path
[QS] garage building doors & edge
[G] entrance of building
[QS] parked cars, vertical tree trunks & building façade
[G] Bicycles in front of entrance
[S] Person exiting building
[S] Group of three trees
[G] Opening towards park, tents in distance

Poptahof – scene 2

[S] edge container & vantage point middle
[S] building and bicycles popping up behind container
[QS[pipe, wall, small pocket space
[QS] green, water, row trees and building behind it
[S] moving cars
[S] reflection & look through window
[S] ventilation rosters
[S] electricity box, graffiti, pocket space
[S] row of trees, vertical elements
[S] garbage containers
[S] parking meter (sign)
[QS] landing bird, moving car
[QS] open space, trees



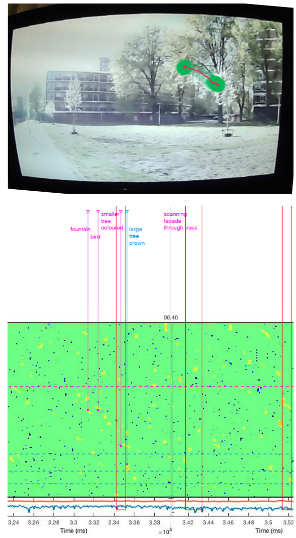
S3- Red container & people in front of them

Poptahof – scene 3

[S] large red container
[QS} row of trees & building behind them
[G] persons & reflection window
[QS] vantage point shaped by container building plinth
[S] building on corner
[QS] buildings distance
[QS] doors to the right
[S] signs
[S] small tree
[QS] row of trees in park

[QS] blue container, walking girl, buildings behind tree
[S] tall building shape

Poptahof – scene 4
[S] vanishing point, portal
[QS] building shapes, path & trees
[S] entrance apartment
[G] fountain
[S] trees,
[S] cyclist & bird
[S] roof school building, tall building distance
[S] entrance & garbage containers
[QS] trees, container, furniture on square

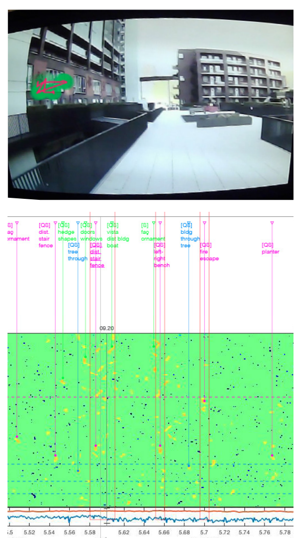


S4- Smaller coloured tree & large tree w/ big green crown

Poptahof – scene 5
[QS] wall edges
[S] parasol, tree & garden screen
[S] small shed
[S] garden screens & window frames behind
[G] antenna
[S] bicycles, kid & lamp post
[S] centre & edges of visual portal

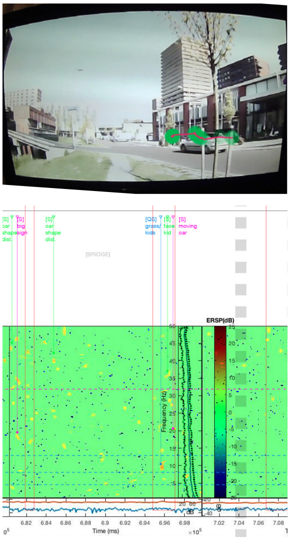
Poptahof – scene 6
[QS] railings, paths, planters & shed
[S] tall building shape
[S] bridge, railing & path
[QS] cyclist, bank edges
[S] fountain, green surface
[QS] water, moving bird
[S] contours bridge, balconies behind slope

Poptahof – scene 7
[G] child with two persons
[QS] gate, stairs & railing
[S] hedge & sign
[QS] building façades
[S] ornament left façade
[G] children's play set
[QS] column, visual portal, balconies, back-entrance
[QS] reflection window, cyclist, moving people, tents, buildings in distance



S7 - Ornaments inside courtyard

Poptahof – scene 8
[QS] moving cars & cyclist
[QS] building plinth, building shape
[S] path & distant building

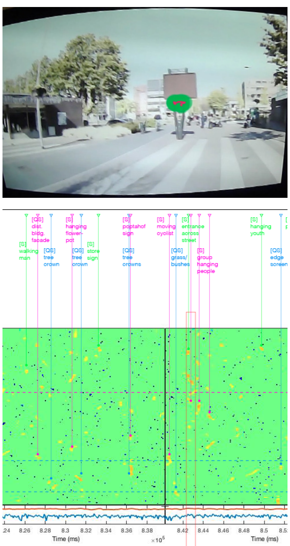


S8 - Moving car-tree

[S] window frames left
[S] tall building right
[QS] walking person, moving car
[S] bridge shape, building behind it
[G] small trees
[G] sign
[QS] building façade ornament, street vantage point, tree & building height
[QS] moving car, children
[QS] main entrance, side-door, person walking

Poptahof – scene 9

[S] fence, basketball court, tree
[QS] trees along façade, balconies
[S] tall building distance
[S] children's playset
[QS] water, railing
[S] sign



S10 - Poptahof sign

Poptahof – scene 10

[S] path centre
[S] red doors
[QS] blue surface, tall building
[S] moving cyclists
[S] tree crowns
[QS] groups of people
[S] poptahof sign
[QS] cars, cyclists, buildings, trees

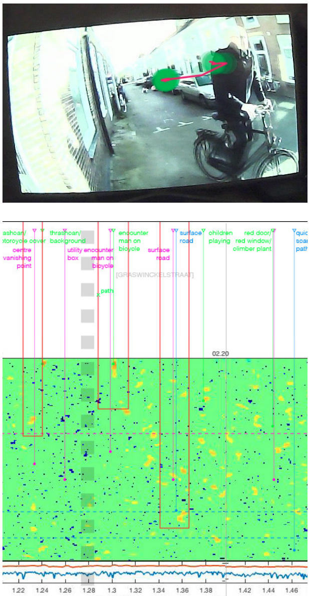
Westerkwartier – scene 1

[S] small tree
[G] face of man walking
[G] vista, vanishing point end of street
[S] trashbins/ electricity trafo
[S] blue door
[G] man on bicycle around corner
[S] sign
[G] children drawing on path
[G] church tower
[S] roof shape corner building
[S] red door
[S] chalk
[S] chamfer corner façade

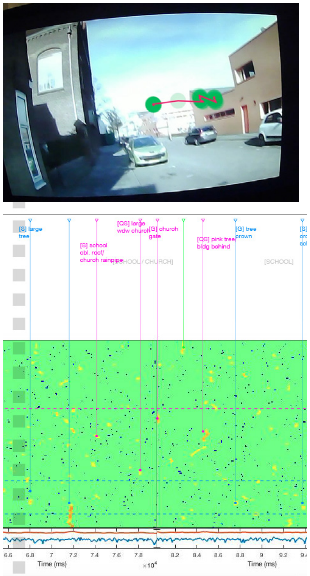
Westerkwartier – scene 2
[QS] roof shapes school
[S] church window reflection
[S] church portals
[QS] school yard, trees, windows school
[S] church entrance
[S] roof shapes
[S] container
[G] artworks on wall
[G] window reflection
[S] chamfered building corner
[S] vertical slim tree
[QS] roof shapes, ornaments

Westerkwartier – scene 3
[S] paintings on wall
[QS] centre vanishing point, post
[S] coloured doors
[QS] left-right façade elements
[QS] bicycles
[S] people
[G] window reflection

Westerkwartier – scene 4
[QS] tree in front of church
[S] church tower
[S] group of cyclists
[QS] parked cars
[QS] roof shapes
[S] tree end of street
[S] church roof & windows
[G] moving car

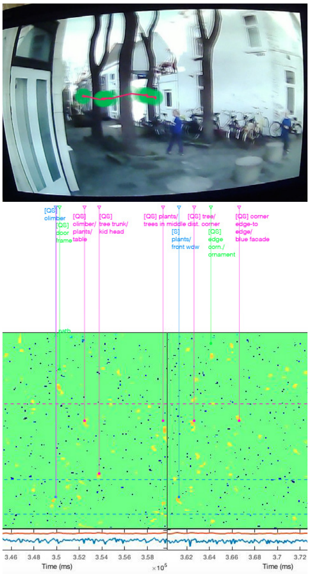


S1 - Encounter with cyclist



S2 - Oblique school roof

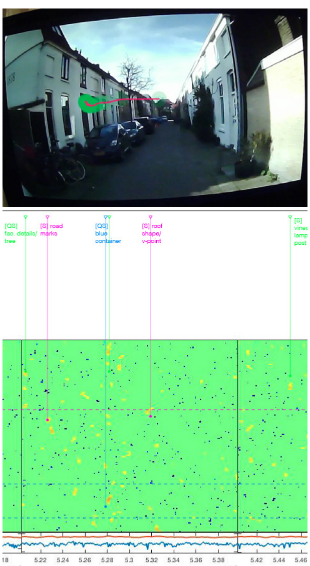
[QS] chamfered buildings
[S] cyclist w/kids
[S] tree coloured leafs
[S] group of bicycles
[QS] overhang shape roof



S5 - Large tree trunks

Westerkwartier – scene 5
[S] children
[S] large tree trunks
[S] tree
[QS] tables, objects in centre
[QS] windows, bicyclces, plants
[QS] blind façade, corner, windows
[S] person exiting building
[G] overhang column
[S] vista
[S] car
[S] window w/ornament
[S] corner building, green door
[S] girl standing
[QS] corner buildings

Westerkwartier – scene 6
[S] red door
[QS] blind façade
[S] sign
[S] terrace right
[G] tree w/ white leafs
[G] face persons walking
[S] shape corner building
[S] climbing plant
[QS] roof shapes
[S] blind white façade
[S] children



S7 - Vanishing point & roofline

Westerkwartier – scene 7
[S] sign
[S] trafo box
[S] vanishing point
[QS] left-right windows
[G] blue container
[S] different coloured façades
[S] tree
[QS] roof shape
[G] face woman
[S] portal, doors
[S] lamp post in centre

EEG frequency spectral perturbation

ERSP's, Pz – T8 coherence, and scanned spatial elements

Patterns of EEG frequency dynamics seem to reoccur in relation to eye-movement behaviour and scanned spatial elements. The most eminent distinction occurs in the synced events in the theta (4-8Hz) to alpha (8-12Hz), and beta (8-40Hz) range.
Concentrations in the alpha range occur most when scanning or gazing at flat green surfaces, large leafy tree crowns in the case of Poptahof, scanning the vanishing point of a clear vista, scanning paths, and quick-scanning building contours.
The beta range seems to relate to surfaces objects that involve a higher form of (re-)cognition and occur when observing: *façade units* such as decorative pilasters, window frames, ornaments, rain-pipes door frames or entrances; *objects* such as tree trunks, (lamp)-posts, signs, or parking meters; objects that refer to *social traces* such as benches, planters, climbing-plants, trash-bins or (groups of) bicycles; discontinuing *building shapes* such as chamfered buildings, terraces, blind façades, or roof dormers.
Higher frequency ranges occur while focusing and gazing on distant or complex elements that require higher cognitive processing efforts, i.e. trying to make something out of what is perceived. These occur at distant objects, reflections on windows, encountering humans, looking at moving cars or cyclists and reading text on signs.

Place-quality appraisal, rather than spatial elements

Referring to qualitative assessments of the participants, it is noticed that descriptions generally involve space-place, or space-occasion relations, rather than architectural or space-establishing elements. Descriptions given are about a certain "town feeling", "cozyness", "crowdedness", "too much cars" "flying birds", etc.

In Poptahof sequences that involve quick-scanning with higher frequency ranges in large open vagues, with several occasions are describes as unpleasant and messy with too much "happening" in the visual array. Negatively described scenes of Poptahof also include elements of social traces and these tend to overrule almost all positive spatial qualities of that scene. For instance, the group of garbage containers and moving cars in scene two that are perceived after gazing at water, greenery, a screen of trees in front of the building, are not mentioned at first. Instead, elements that involve more awareness (in the beta frequency ranges) are mentioned, whether it is positive or negative. The same applies to appraisals in Westerkwartier. Elements appraised positively include colorful doors and walls, beautiful planters, climbing plants, or bicycles; all place quality agents that include human interference, and moreover fall into the higher complexity category in the preference model. Negatively appraised elements involve sudden cars and cyclists in the field of view. Even though the sequences in Westerkwartier were mostly described with high complexity features, only few occasions were described as negative, whereas in the Poptahof sequences described above, occasions, both PQA's and SEE's contribute to be perceived as "visually messy", or "clear and boring" (Kaplan & Kaplan, 1989).

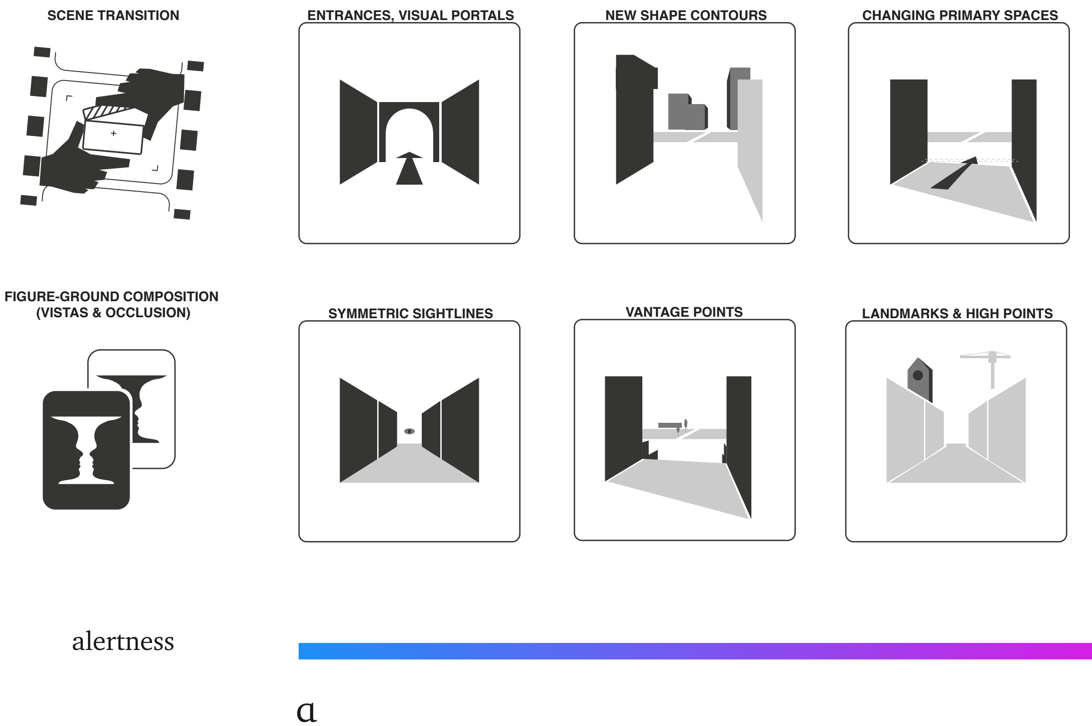
Relation between X- and O- typed spaces, vagues, suggests, space establishing elements, and place quality agents: the perception of space with objects vs. perception of place

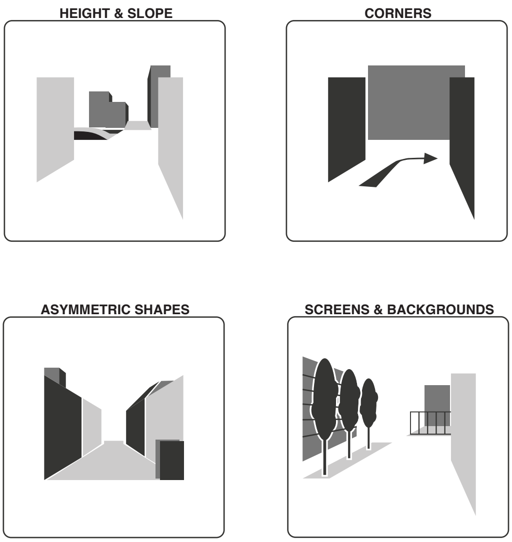
Looking back at the results, there are several patterns perceived spatial elements that reoccur and are different per case. In scenes of Westerkwartier, the combination of narrow and more explicit spaces, both rhythmic and dynamic shapes in space establishing elements that are relatively in the same dimension range, with complex and humanly interfered place-quality agents, seem to be more harmonic and in balance in the appraisal descriptions. Eye-tracking results, synced with EEG dynamics show a pattern of rhythmic quick-scans, (and scans) of the overwhelmingly complex humanly interfered PQA's in combination with façade elements both in the alpha, beta, and occasionally in the gamma range; scans of paths, building (roof) shapes, and the end of the street, in relation to clear vistas and centric vanishing points in the alpha range; reoccurring scans in the beta range of highlighted chamfered buildings in the corner with differences in shape, colour, texture, or highlighted ornaments; also in the beta range, trees without leafs, or trees with coloured leafs and oddly shaped disruptions or discontinuations of the rhythmic SEE & PQA pattern in the visual array.

In Poptahof, scenes and the sequences in the scene are more diverse, changing from X-typed suggests, to vagues, and more defined spaces. Generally, there are far less PQA's that resemble human interference and less complex PQA's perceived at the eye-height. With greater distance to surfaces or screens on the *side,* less foreclosure coherence in screens and surfaces, and less visual noise in the form of complex or humanly interfered PQA's on surfaces, attention and aware perception (that occurs in the beta range) flows to objects, or group of objects such as tree-trunks or parked cars. Sequences where this phenomenon occurs extensively, with a higher number of alertly perceived objects and occasions, and with less time to process all objects (quick-scans) are appraised negatively. There is a substantial difference in the perception of spaces with a balanced SEE-PQA relation (places) and spaces with multiple objects in them.

Events that show reoccurring patterns in the ERSP analyses of Pz – T8 channels, and gaze behaviour, are categorized into the following:

SPACE ESTABLISHING ELEMENTS (SEE's)



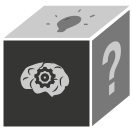


β

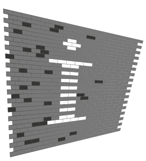
γ

Reoccuring SEE - alertness pattern (author)

OBJECT (RE)COGNITION

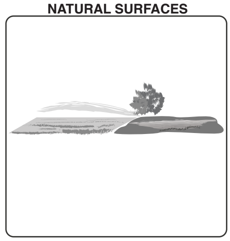


SURFACE INFORMATION / OBSERVATION

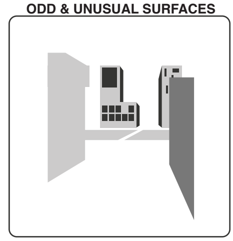


PATHS & ZONES

NATURAL SURFACES

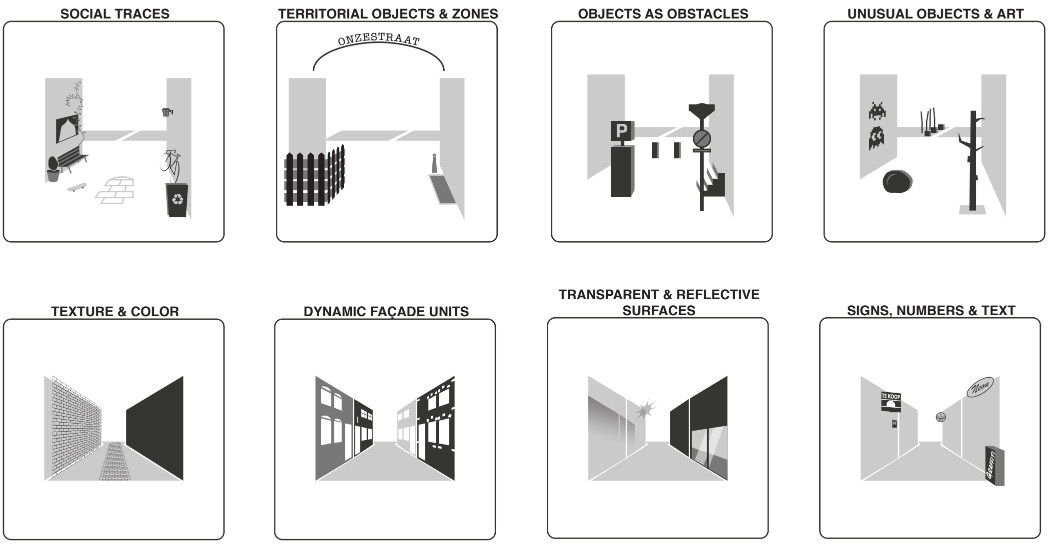


ODD & UNUSUAL SURFACES



alertness

a



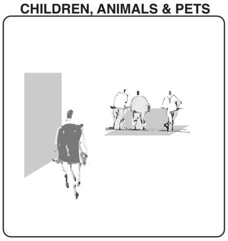
β

γ

Reoccuring PQA - alertness pattern (author)

HUMAN ENCOUNTER SITUATION

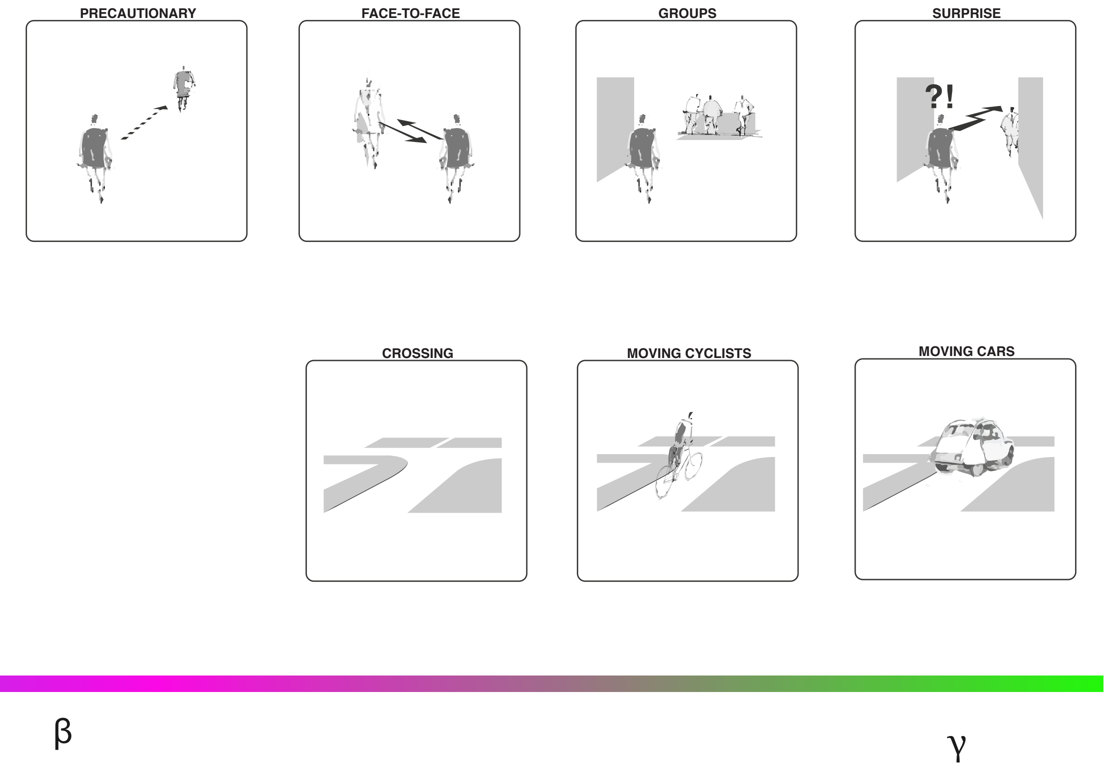
CHILDREN, ANIMALS & PETS



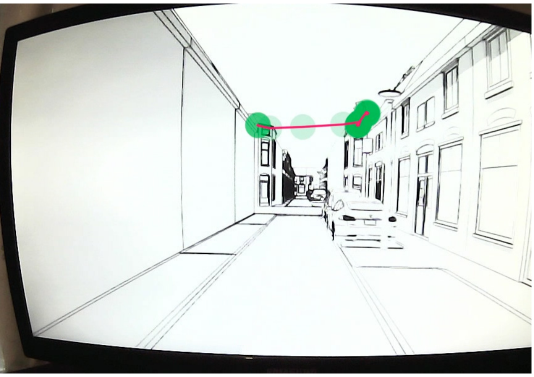
TRAFFIC ENCOUNTER SITUATION

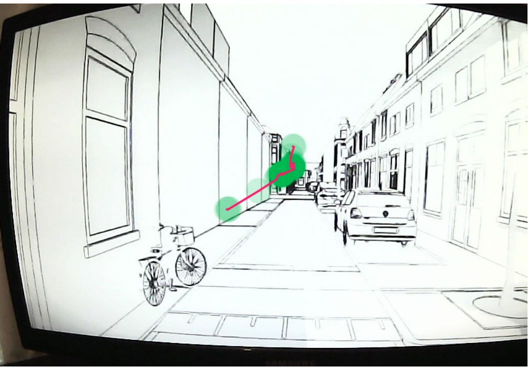
alertness

a



Reoccuring occasion - alertness pattern (author)





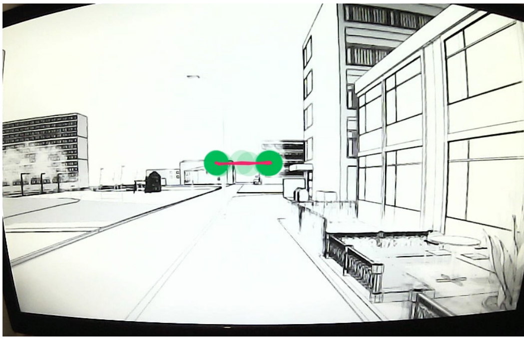
Simplified models

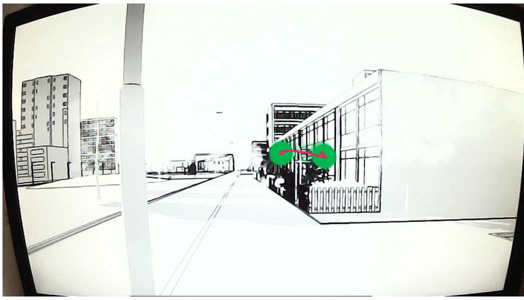
For the purpose of exploring whether eye-tracking results, EEG patterns, and the spatial elements that involve results show similar patterns in simpler representations of the visual world, two models are created that are based on the spatial context of the cases of Poptahof and Westerkwartier. In a series of animations, a straight line follows a fixed route at eye-level in the model, with variations that slightly change the SEE coherence, the presence of place-quality agents, and rhythm/datum patterns.

Westerkwartier:
Gaze behaviour shows the same occurrences as in the videos. The rhythmic façade surfaces are quickly scanned from left to right, while surfaces that differ from the rhythm are gazed upon longer. Frequency concentrations in the beta band of channel Pz and T8 occur mostly at distinctive surfaces and objects in the distance. Frames where the rhythmic pattern is deliberately disrupted (with a blank façade, or less window frames) are scanned once or twice very briefly with a short peak in the beta band, followed by the continuous scanning motion of the more complex elements.

Poptahof

For the Poptahof model, more complex PQA's (gardens, dish, and furniture) are added and subtracted from the model, followed by a volumetric change of pure shapes and less lines. More alert reactions occur when scanning human PQA's. With the absence of complex PQA's, attention goes to distant high points, especially the pointy roof of the school building, resu;ting in longer gaze points.

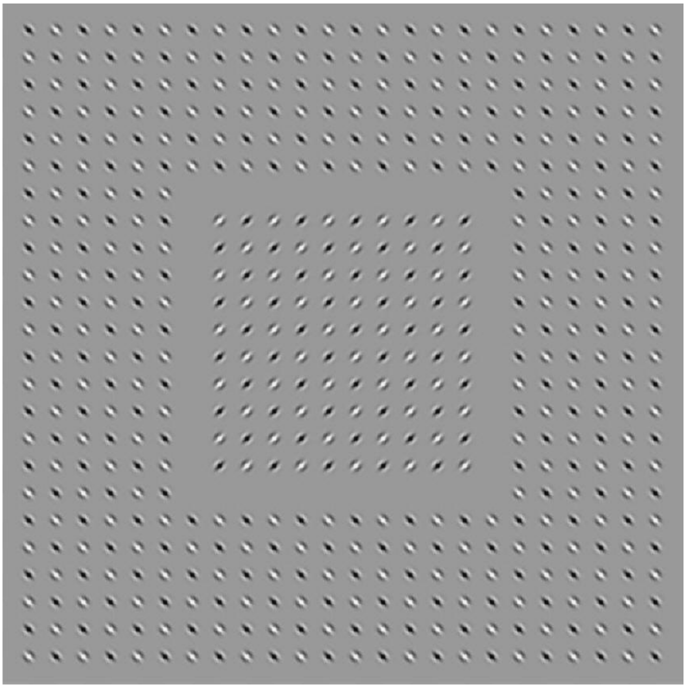


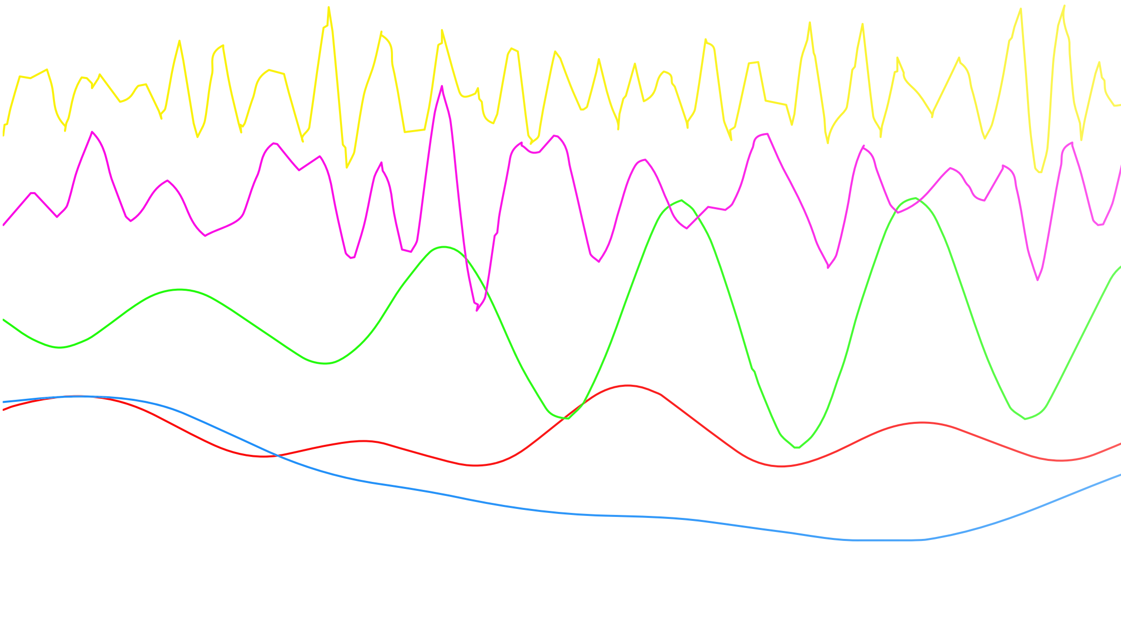


To summarize results, concentrations in the alpha range mostly occur when quickly scanning the primary space its *extents*, *vanishing points*, *end of streets*, the *shape* of space extents, *paths and lines*, and *natural surfaces* (including larger tree crowns).
Concentrations in the beta range occur when observing: *façade units* such as decorative pilasters, window frames, ornaments, rain-pipes or door frames; *objects* such as tree trunks, (lamp)-posts, signs, or parking meters; objects that refer to *social traces* such as benches, planters, climbing-plants, trash-bins or (groups of) bicycles; discontinuing *building shapes* such as chamfered buildings, terraces, blind façades, or roof dormers. Higher frequency ranges occur while focusing and gazing on distant or complex elements such as, *reflections* on windows, *encountering* humans, looking at *moving* cars or cyclists or reading text on *signs*.

Another occurring pattern, which will be elaborated in the next chapter, comprises the level of complexity in sensory information, and the reoccurring SEE's, PQA's, and occasions. The more complex set of information the occurrence has to offer, the higher the raised alertness in the beta-band. If we assume the ecological approach to perception, where it states that visual perception occurs through stimulus information rather than sole stimulation, and where *optical flow* is essential for actually perceiving that set of sensory information, we have to consider the factor of *motion* for explaining the occurrence why some spatial elements (or, in this research, why some moving pixels on the screen) are perceived more alertly than others.
The next chapter takes the results from the ERSP-video analysis and dissects the spatial occurrences into an architectural and urban design vocabulary.

PART III





8. IMPLEMENTATION IN DESIGN

Like with many other forms of art, whether it is in music, visual arts, or sculpting, the value of artefact appraisal heavily depends on our own cognition, feelings, or narrative; what we (our minds) make of the created artefact at a specific moment and place. However, as designers, artists, composers, creators etc. with certain intentions, we try to influence how people perceive the artefact, not only by using intuition, skill and craftsmanship in the broadest sense of *technê*, but also applying methods (sometimes unintentionally) from scientifically backed theories (e.g. studies on musical harmony, image composition, proportion & ratio, colour theory, etc.). Even though architecture and urban design on the level of visual perception fall in the category of a more complex construal level (Stolk, 2015), positively appraised urban design can be argued and reasoned through psychological research on the relationship between our environments and how we perceive them, or more precisely in the context of this research; the relation between visual sensory information, and our physiological reaction in gaze behaviour and brainwave activity.

From theory to design artefacts

The following section captures existing guidelines on how urban design principles can influence visual perception and appraisal, and incorporates results from the video-ERSP analyses, aiming to translate theory into a common urban design language.

Context, user-participants & design goals

With the exception of comprehensive area developments, contemporary urban design sites usually include an existing urban environment context. Taking the Yorkes-Dodson law (Berlyne, 1971; Steffen, 1981) as a starting point, we should ask ourselves what the goal is in terms of arousal or activation in overall, in relation to the surrounding urban context, and for a specific section of the plan. Do we want to create a peaceful living quarter or a vivid area? Do we want to continue the surrounding setting, or do we want to create contrast and tension with the neighbouring district? As the results from the video-ERSP analyses show, the smallest mis-)placement of objects or elements in relation to a person's visual field can evict a burst in the heightened state of alertness in the brain. Naturally, the user-participant its field of view is selective and undeterminable, and not everyone is an architectural photographer who can capture beautiful image compositions. Fortunately however, we *can* influence the visual world, and we can be as specific as we want with it, designing preferred streetscapes, vistas, enclosures, points of interests, by using design principles (axis & symmetry, hierarchy, contrast, rhythm, datum, complexity, and transformation). With these principles, we can play in order to scape overall harmonious (or, depending on the goal, disharmonious) environments. As we will see in the following sections, we should not confuse peace and harmony with dullness and monotony. Instead, the overall psycho-perceptual quality of a specific urban environment relies on finding an ideal balance in the rather complex tension field of psycho-perceptual urban design.

Information potency and redundancy

As is mentioned in the theoretical framework, each perceived phenomenon usually contains a certain amount of uncertainty, which is referred to as *information potency*. The more unpredictable the phenomenon is, the greater the potency to acquire and process new knowledge. In contrast, predictable phenomena can lead to an overflow of unnecessary information: *information redundancy*. With our visual system set to track changes and discover new information in the environment, perception involves both: information that is partly new, unpredictable, and unexpected, and partly known, expected, and predictable. As designers we can influence the best of both worlds in order to strive for a desired balance in information potency and redundancy.

For visual pleasantness (that evokes positive appraisal) it is important for the mentioned environmental information

Sensory deprivation and visual nuisance

input balance to achieve a minimum level of arousal, because both absence and excess of environmental stimuli can lead to perceptual stress. Urban environments with poor variance, complexity, contrast, and details can lead to *sensory deprivation*: Long term stay in a uniform and monotonous environment can lead to boredom, depressiveness, irritability, and nervous tension. The UP (user-participant) its adaptation-regulation leads to greater openness to the environment, triggering the orienting response, (a term first coined by Pavlov which is also known as the "Что такое?" or "What is it?" reflex), raising the information supply whilst lowering the redundant part. If there are not enough resources to cope with this information demand, it leads to stress. In general, people prefer cognitive uncertainty to a certain extent, more precisely, in relation to a person's processing capacity. Consequently, depending on the target group, the complexity should not be too great: the environment must encompass surprises, but must also be clear in order to keep a general overview. The need for information variety thus is not unlimited. Too much sensory impulses in a short period of time leads to overstraining and discomfort. This visual nuisance or cognitive overload mostly occurs in a crowded city where one is continuously activated with a wide range of visual information while the auditory and other sensory systems also work overtime. With little occasion for rest and recovery, a longer stay in such environments can evoke psycho-somatic disorders in the long run. The adaption-regulation lowers the information input, filtering only the most relevant information (defensive response). While information input is lowered, the defensive response tries to heighten the redundancy of the visual system (Steffen, 1981).

Under-stimulation raises orienting response... What is it?

Over-stimulation causes information redundancy. You try to avoid collision.

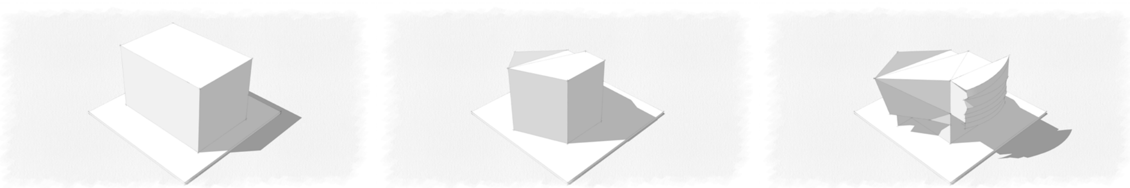
For designing regarding the psycho-perceptual system it is thus essential to find the ideal balance between the existing context, users, and potential sensory information. To make this more practical and applicable in urban design, according to what is obtained in literature, and what is observed in the ERSP-video analyses results, the visual world of common streetscapes in urban environments is categorized into: *architectural complexity*, *complexity in urban design* (Steffen, 1989), and following the ERSP-video results that support the Gibsonian optical flow theory, *complexity of relative motion.* The section below dissects the categories further into guidelines and describes how we can influence the sensory information complexity in built environments in search for an ideal balance. Note that all guidelines are derived from the perspective of how we perceive streetscapes as we walk, at the eye-level.

Architectural complexity: Volume and details

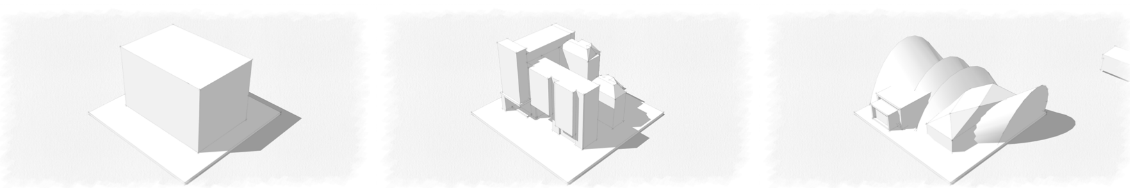
The architectural complexity guidelines below define how to achieve a certain complexity in visual sensory information on the level of a single building. This assumes we perceive a single building, disregarding the surrounding elements. The complexity scale is rather relative to the building size and our distance from the building: the larger the building, the more effort is needed to create complexity, and, the greater our distance from the building, the less information in detail can be perceived. E.g. at a greater distance texture can become redundant, while articulation can replace its complexity-increasing function. The architectural complexity tension- field include following elements:

Arch_volume

Plasticity: The extent of three-dimensional deviation of a prismatic building form.

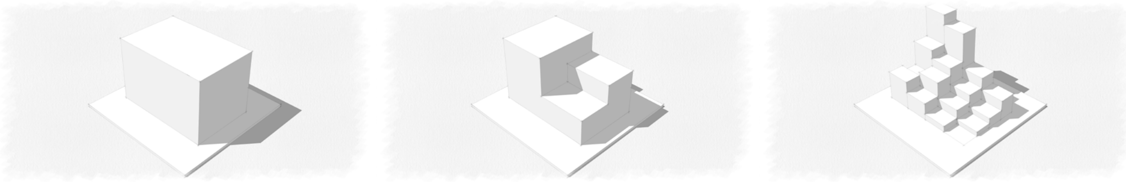


Articulation: Three-dimensional division of the total building appearance into recognizable parts that retain a certain relation with each other.

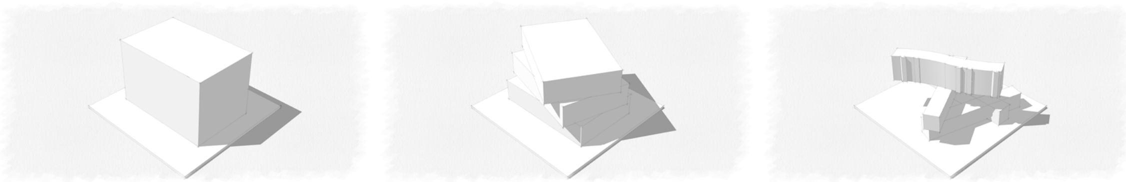


complexity

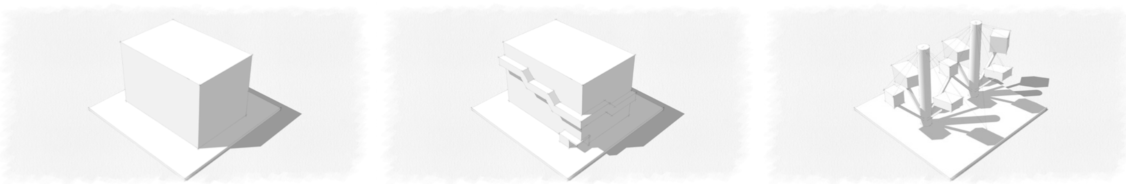
Height difference: Difference in building height that is expressed through the roofline.



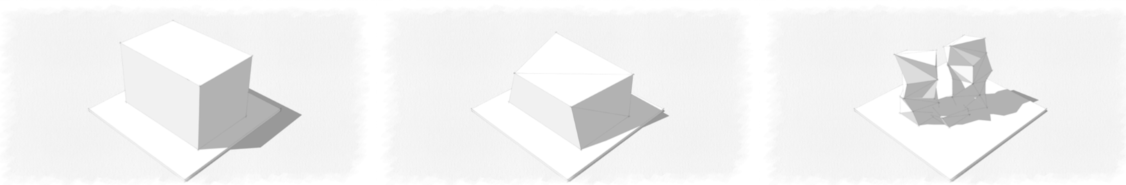
Difference in direction: Difference in the horizontal plane of the building (except for corner joints).



Special elements: Added elements that are not living quarters (staircases, entrances, portals, etc.).



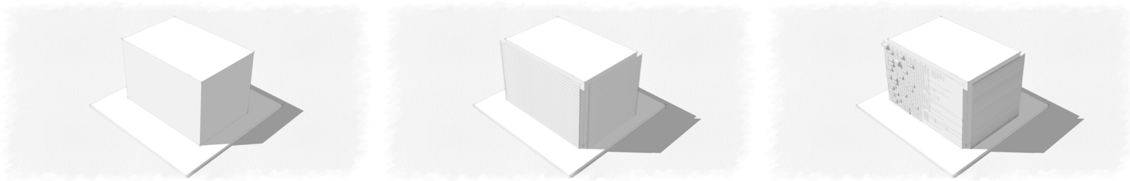
Oblique lines: Oblique lines that visibly differ from the orthogonal (both horizontal and vertical) axes of the building.



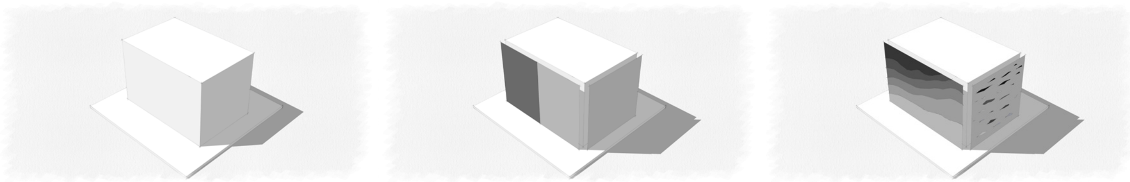
complexity

Arch_details

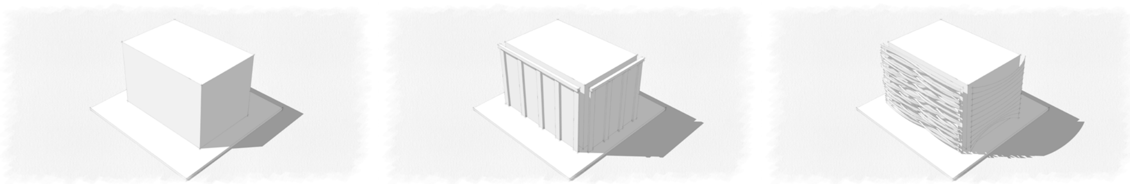
Texture: Variety of applied materials in the façade, ordered by surface structure.



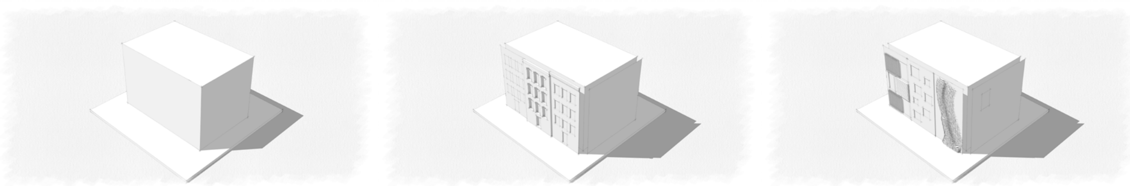
Colour (and brightness): Variety of applied materials in the façade, ordered by colour and brightness.



Plasticity: The extent of deviation from the basic flat surface, both horizontal and vertical.



Articulation: Surface division of the façade into recognizable parts that retain a certain relation with each other.



complexity

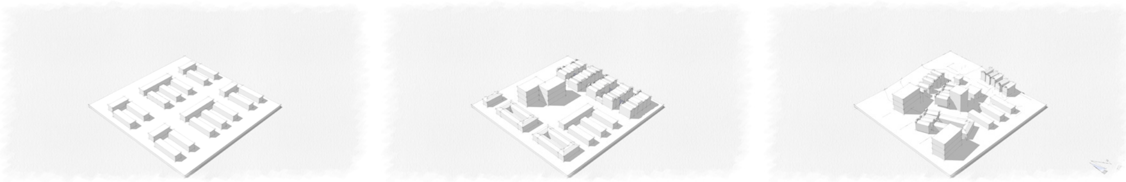
Complexity in urban design: Spaciousness, buildings, and details.

While architectural complexity encompasses single buildings, the relation of the buildings with the surrounding (urban) context, multiple buildings, or building blocks is even more relevant in psycho-perceptual design, since this relation can define the complexity of perceived scenes of our field of views in the visual world. The interrelation of these elements can make-or-brake a scene: a very complex, diversiform, and detailed building with an impressive façade can lose its value when it is surrounded by buildings of the same complexity (due to the cognitive overload our defensive reaction will filter only relevant information, thus making excessive information in the visual system redundant). In a crowded shopping street, the majority of people probably will not even notice the façade details.

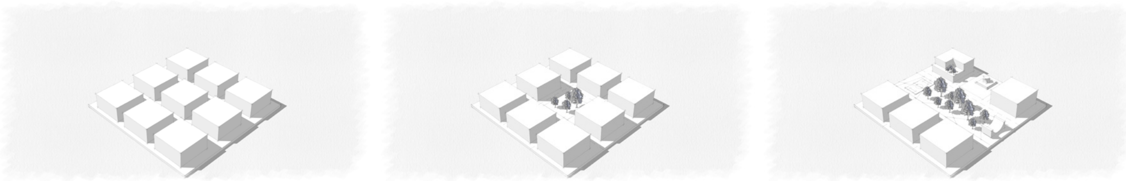
A simple monolithic bright cube placed on a forest hill, near a river on the other hand, might evoke more positive appraisal because the complexity of the setting, combined with the building-setting contrast will suffice in terms of information processing. Given the interrelated complexity of these elements and their countless combinations or design possibilities, the existing context should be considered carefully in order to achieve an ideal balance of the bigger picture. These guidelines include:

Urb_spaciousness

Variety in sequential spaces: Extent in which different urban spaces alternately occur on a route.



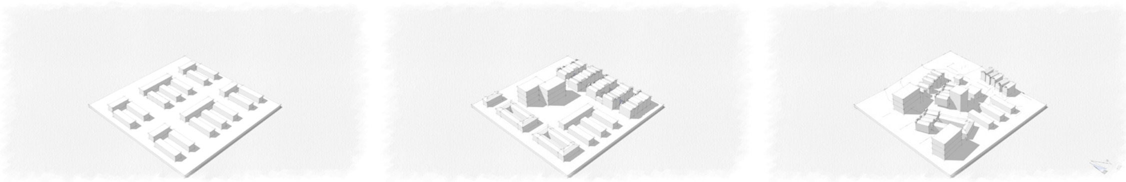
Variety in urban spaces: Extent in which different urban spaces simultaneously occur in the area.



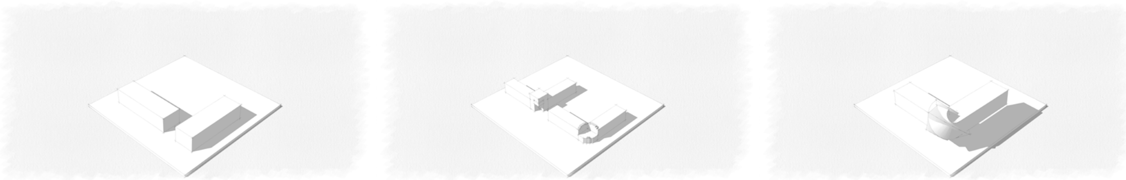
Special spaces: Spaces that differ in both form and function from the usual residential spaces in the area.

Urb_buildings

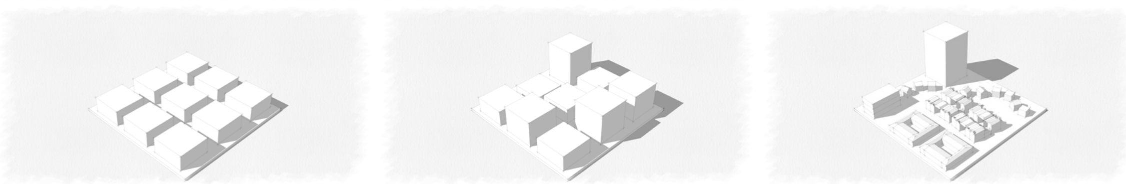
Variety in appearance: Variety and distinctiveness in the occurrence of building appearances in the area.



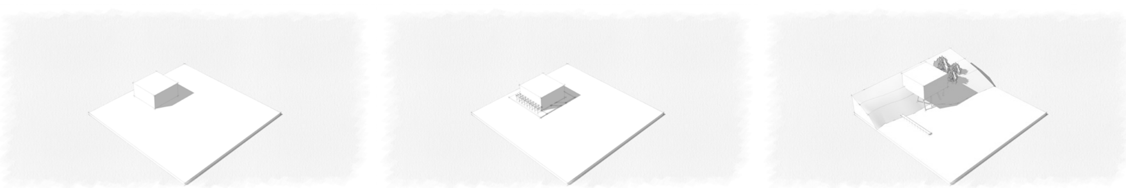
Corners: The extent of corner connectedness of buildings, and their appearances.



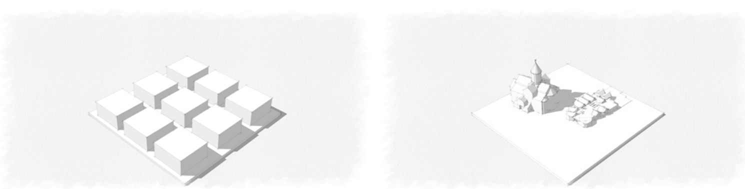
Variety in type: Extent in which different building types occur.



Transition building- surrounding: The way the building is situated in- and transitions to its surroundings.



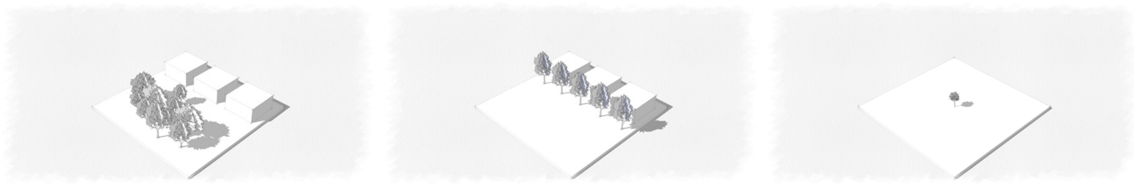
Special buildings: Occurrence of special buildings such as shops, libraries, schools, churches, etc.



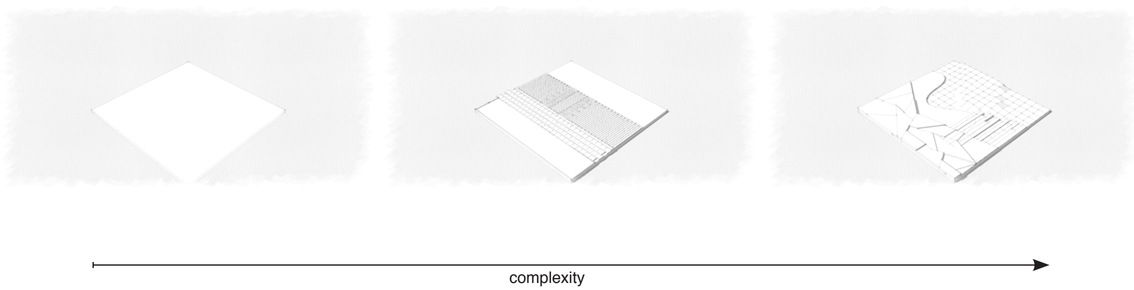
complexity

Urb_details

Planting: Occurrence of planting as contrasting, concealing, or highlighting element.



Pavement: Occurrence of lines, texture, and structure.

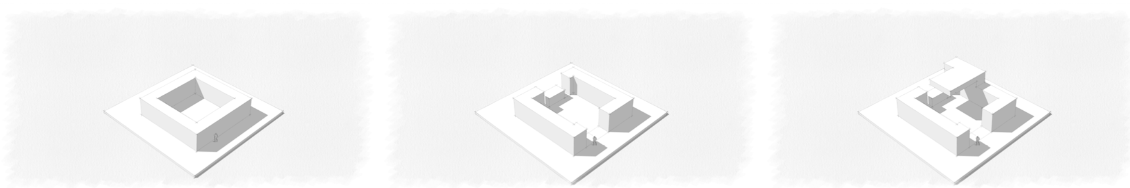


Complexity of relative motion

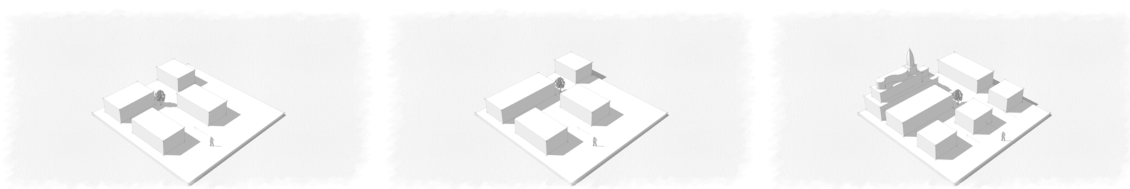
As is explained before, our visual system is set to track and detect changes in the visual field. When an observer moves through a scene, the objects, surfaces, and edges create the apparent pattern of motion, which is referred to as the optical flow. While the guidelines above create the three-dimensional scene and its value of complexity in static information, the guidelines below address the essential, but yet often neglected factor of information complexity in relative motion.

Spc_motion

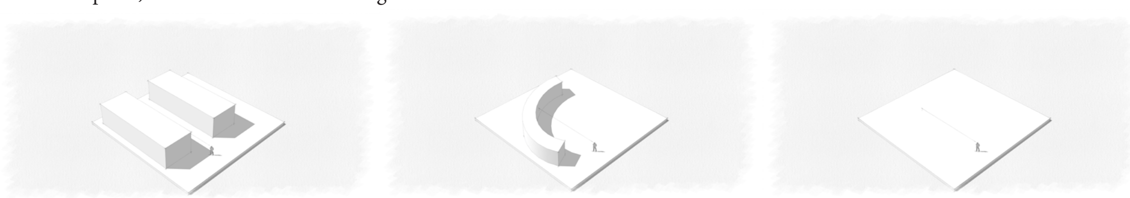
Enclosure: Extent to which the scene deviates from an enclosed (convex) overview.

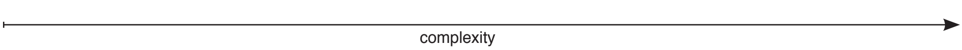


Expectation and surprise: Variety in which the composition of architectural- and/or urban design elements (the scene) provides occlusion and revelation.



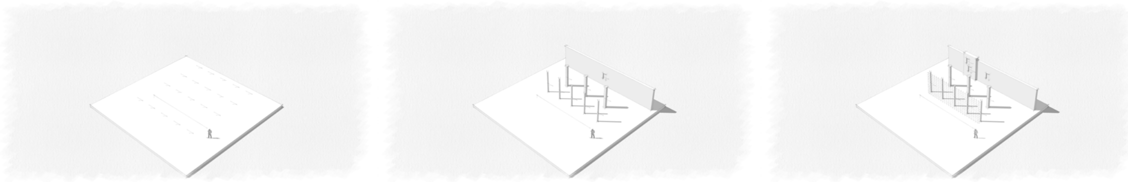
Vanishing point: Extent to which the scene deviates from a clear vanishing point, where lines seem to converge.



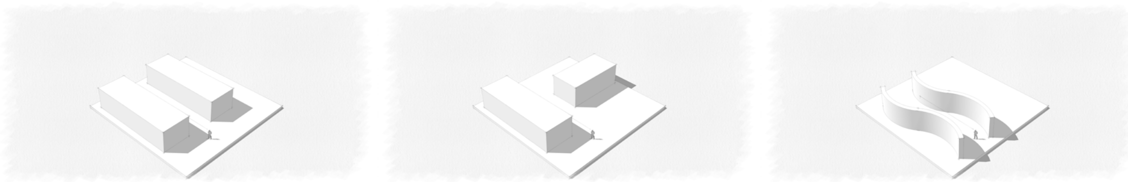


Fig_ground motion

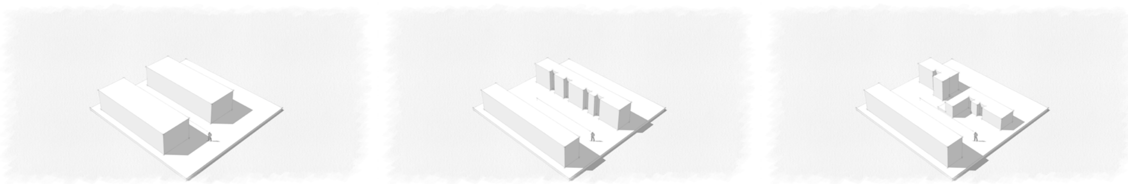
Object placement: The variety in type and rhythm of object placement in relation to the background.



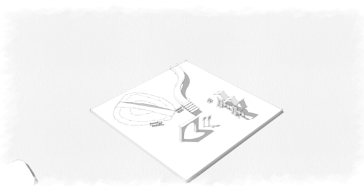
Direction of flow: Extent to which longitudinal flow deviates with the occurrence of lateral (or radial flows. architectural- and/or urban design elements (the scene) provides occlusion and revelation.



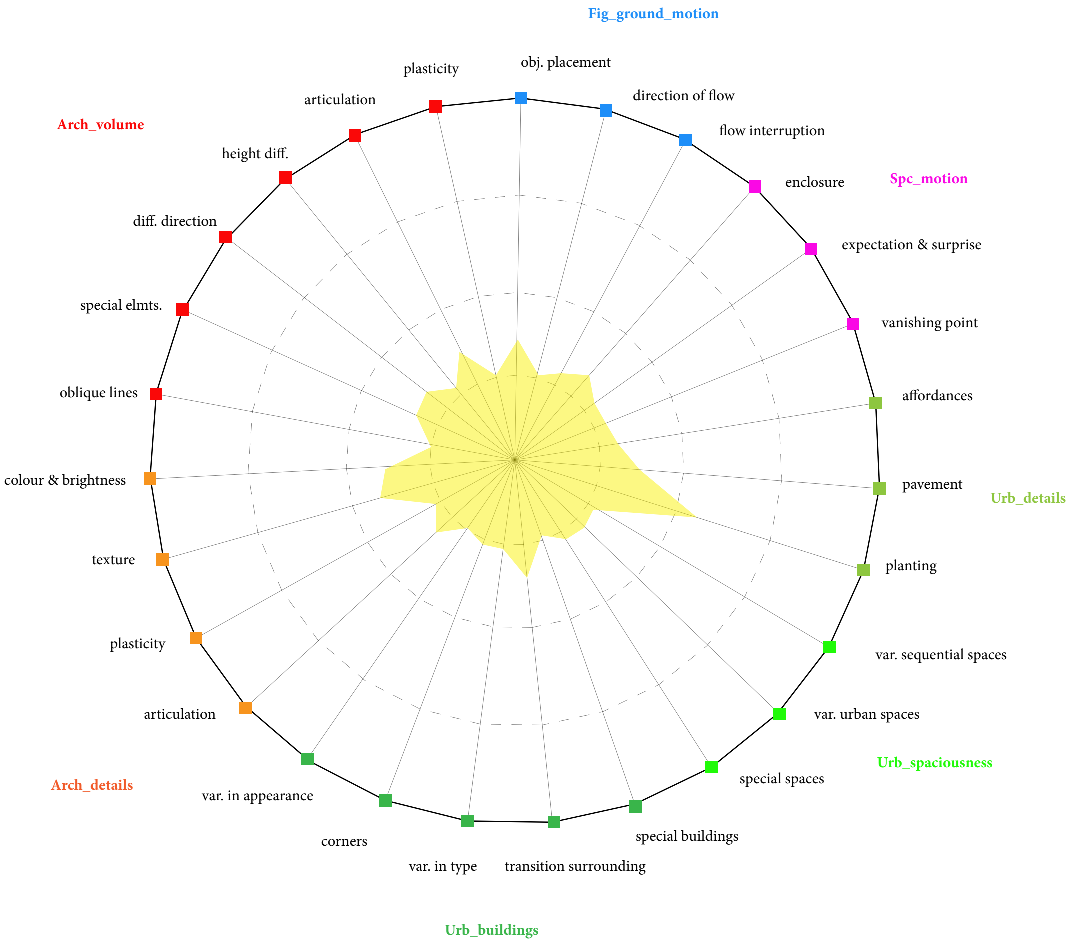
Flow interruption: Variety in rapid changes of continuous flow



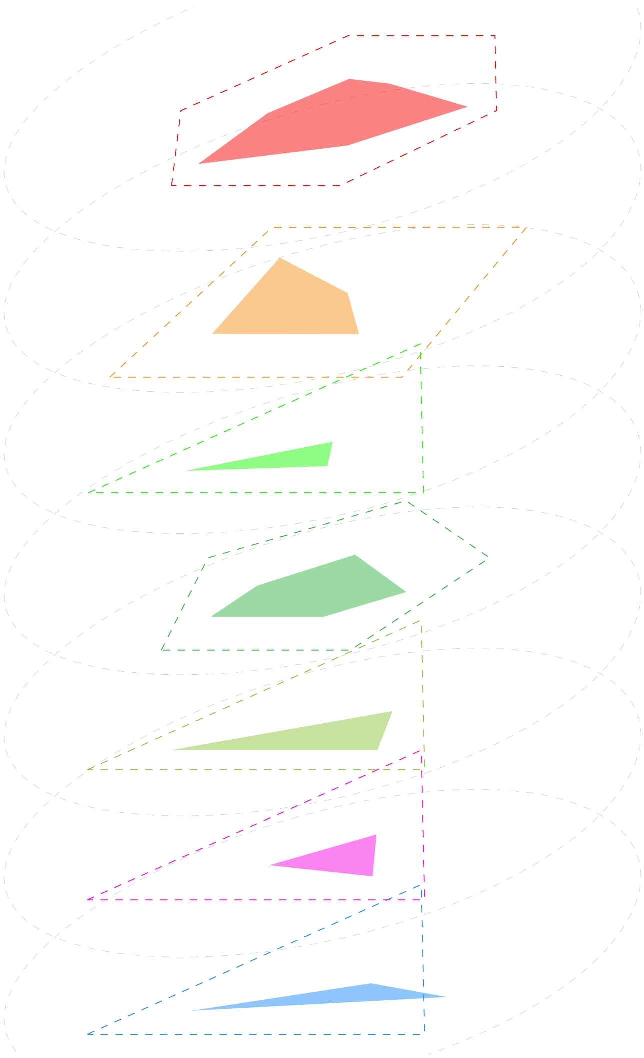
Affordances: Variety and clarity of surface or object interaction



complexity



In summary, putting all complexity layers together in a diagram gives us a general overview that can be used to determine the spatial-perceptual complexity of urban scenes. Depending on the urban context and design goals, the overview of spatial complexity layers can be used to relativize and balance the tension field:
A scene with very complex "postcard" architecture might not suit a very complex urban environment or a scene with extremely dynamic relative motion, unless that effect is created intentionally.
To illustrate how we can express these layers of complexity in urban design, two existing example cases are elaborated in the following sections.



Arch_volume
plasticity
articulation
height diff.
diff. direction
special elmts.
oblique lines

Arch_details
colour & brightness
texture
plasticity
articulation

Urb_spaciousness
var. sequential spaces
var. urban spaces
special spaces

Urb_buildings
var. in appearance
corners
var. in type
transition surrounding
special buildings

Urb_details
planting
pavement
affordances

Spc_motion
enclosure
expectation & surprise
vanishing point

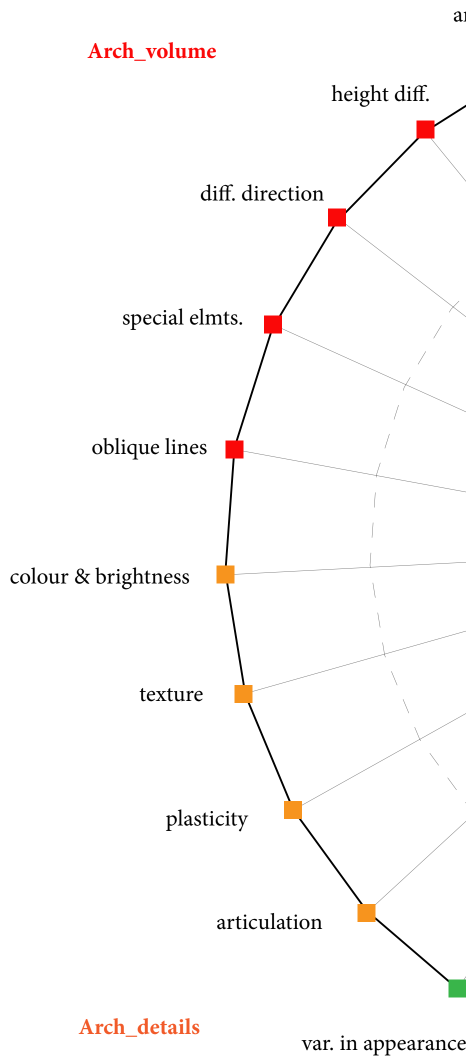
Fig_ground_motion
obj. placement
direction of flow
flow interruption

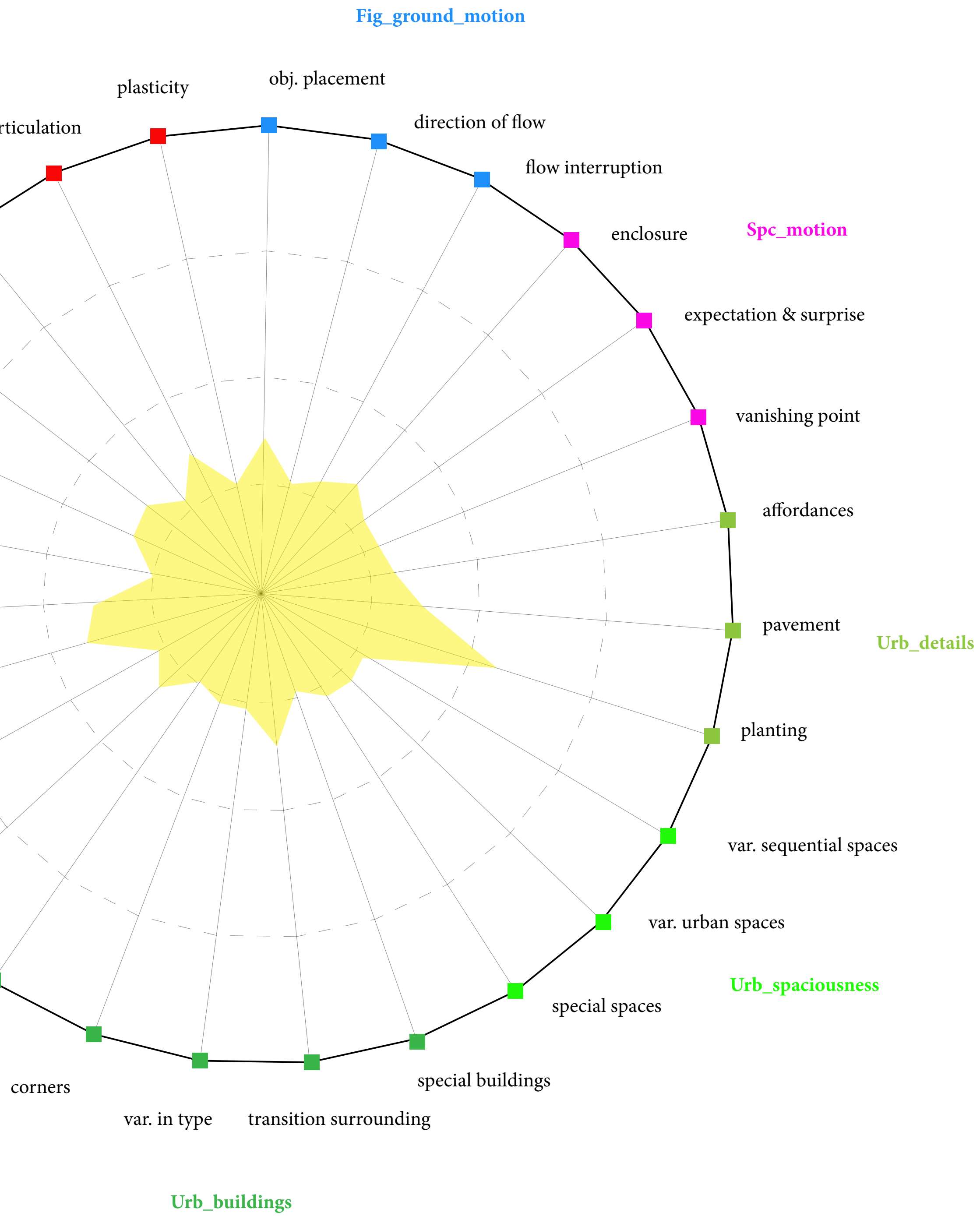
Example case: Mastbos, Amsterdam Noord

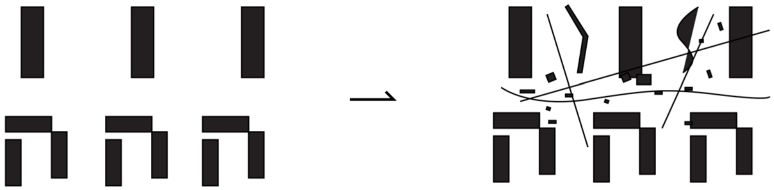
Example case: Mastbos – Amsterdam Noord

With the exception in the use of large green spaces and planting as contrasting element in combination with large monolithic architectural volumes, the visual sensory information in terms of architectural complexity, and complexity in urban design, scores rather low in almost every sub-category. Referring to the mentioned guidelines, we can influence the complexity of visual information, giving the observer more complex set of information.

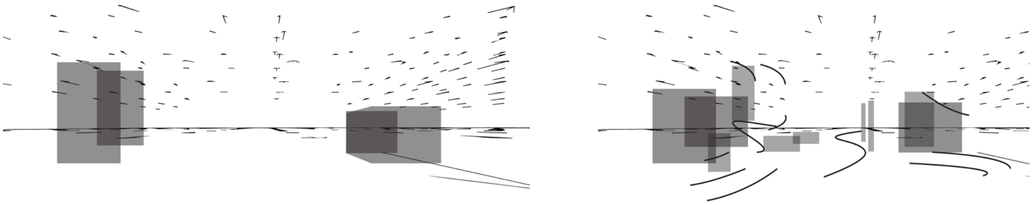
In order to raise the arousal potential of the streetscape, we can change the visual composition in the tension field of design. Depending on the context, design goal, and design scope the section below exemplifies how certain guidelines can be expressed through design in three stages of rigorousness and level of intervention.




Fig_ground_motion
plasticity
obj. placement
rticulation
direction of flow
flow interruption
enclosure
Spc_motion
expectation & surprise
vanishing point
affordances
pavement
Urb_details
planting
var. sequential spaces
var. urban spaces
Urb_spaciousness
special spaces
special buildings
corners
var. in type
transition surrounding
Urb_buildings



From steady optic flow



to datum & disruptive flow

before

impression after

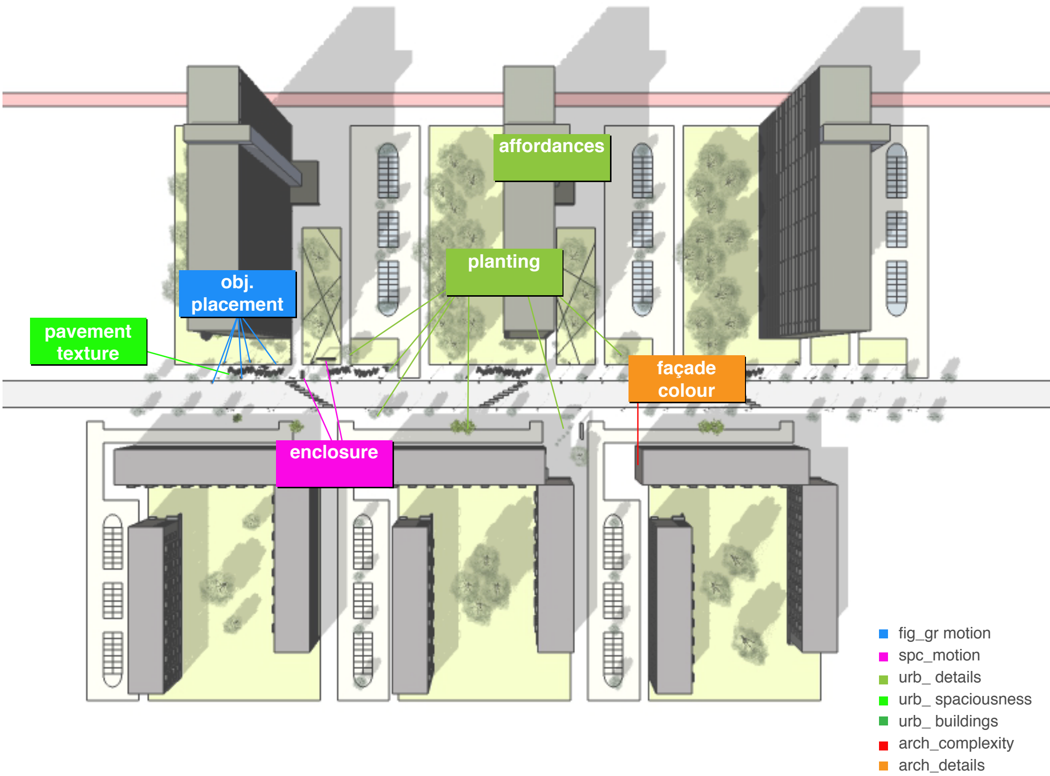
Minimum interventions

Vertical object rhythm (and datum), visual buzz, pavement texture, and apparent occlusions

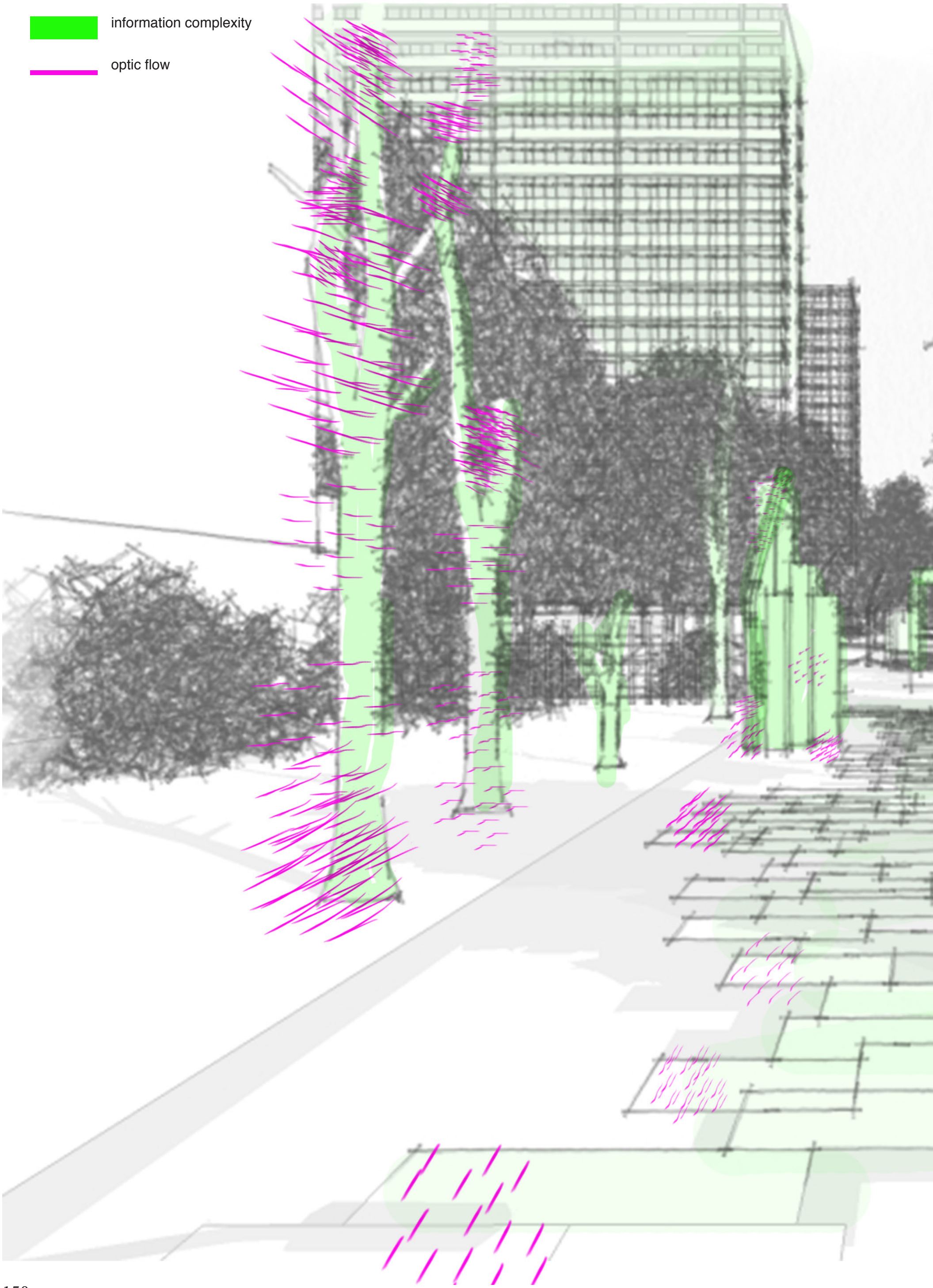
The existing orthogonal building arrangement and treeline in the streetscape provide a straight and predictable vanishing point that accentuates the relatively long distance of the road. Changing the type, size and placement regulation in trees can already change the complexity of visual flow radically. Placing trees, deviant lamp-posts and vertically oriented artwork strategically in the street profile increases the sense of relative motion, giving the observer a more abrupt flow of visual stimuli instead of the original steady and predictable rhythm.

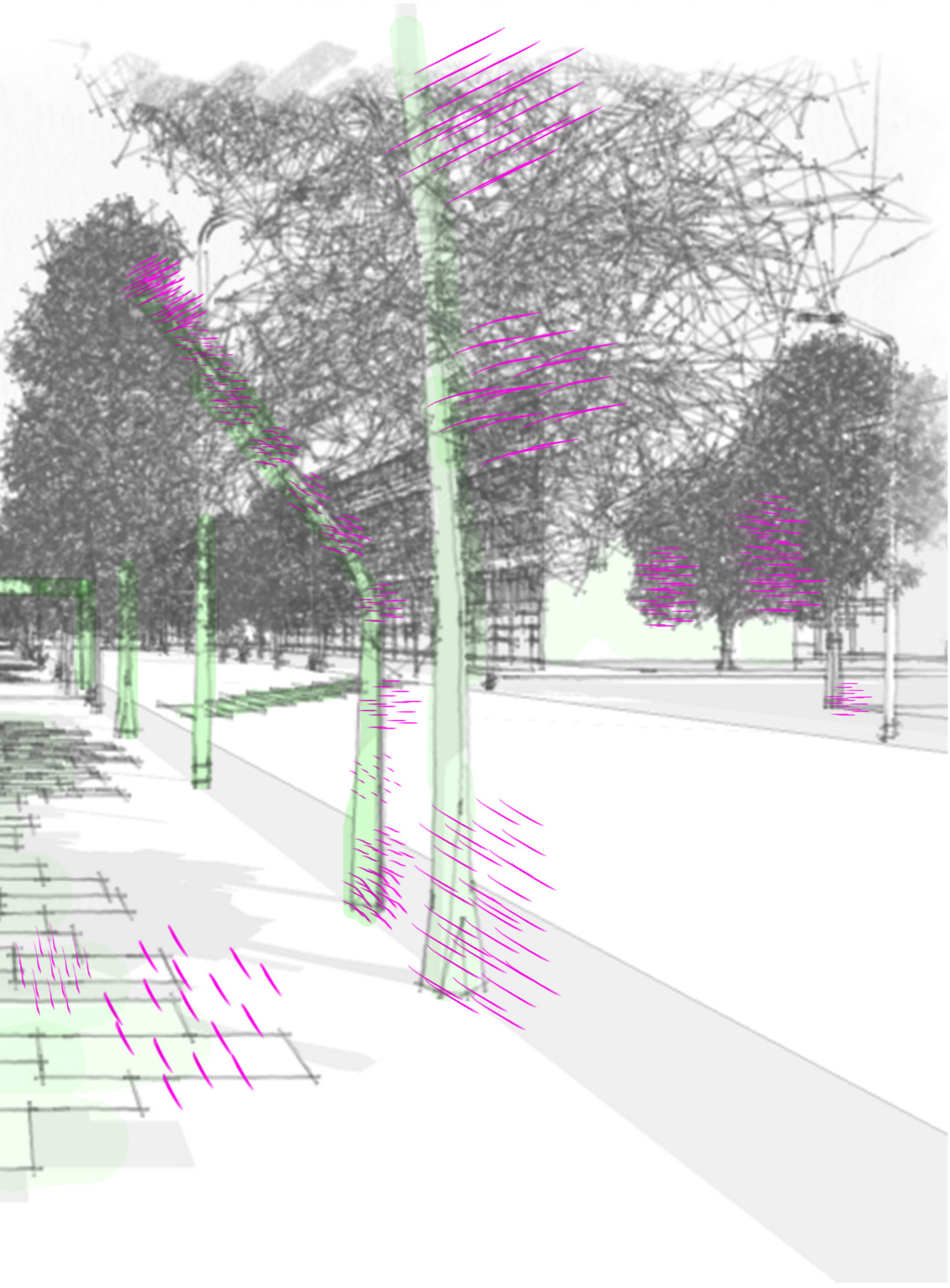
Murals or image projections on a blind façade that stick out are great ways of creating visual buzz in the scene, then again, overusing leads to predictability. Partly changing the colours of balcony panels is also a minimum intervention that has a great visual impact in façade complexity.

Public art in the form of screens (as a space-establishing element) can be used to create apparent occlusions and revelations if combined with interesting elements in the background.


affordances
planting
obj. placement
pavement texture
façade colour
enclosure
fig_gr motion
spc_motion
urb_ details
urb_ spaciousness
urb_ buildings
arch_complexity
arch_details

Variant 1 optic flow

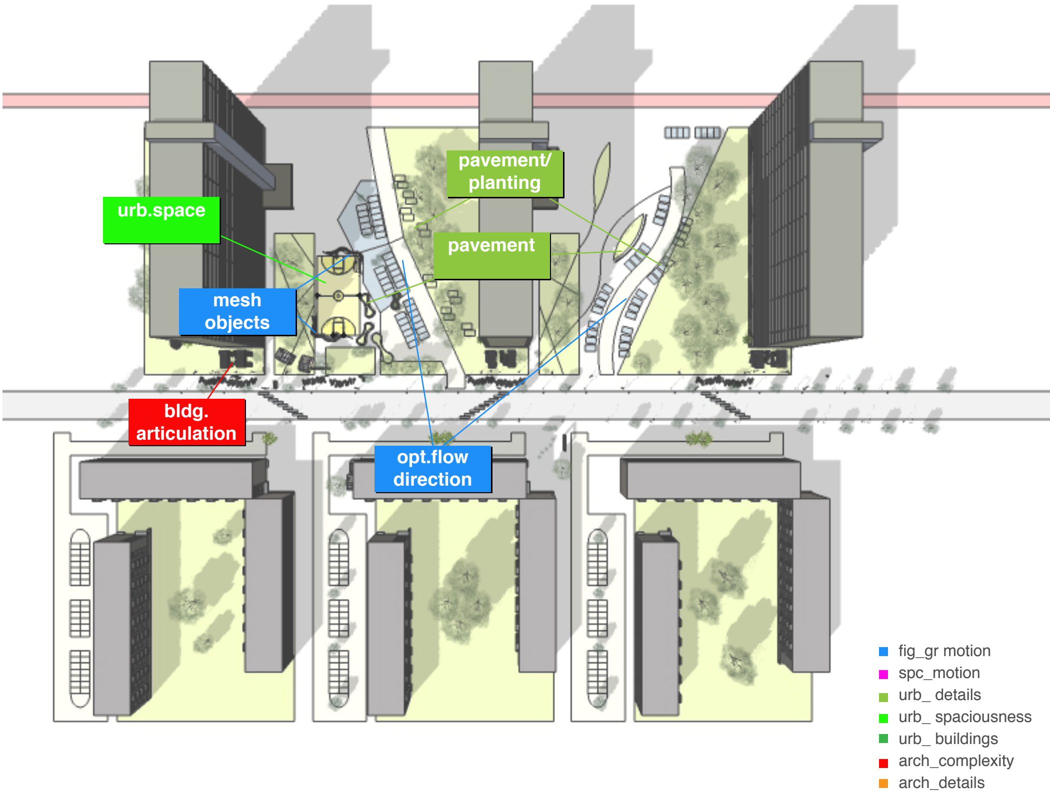




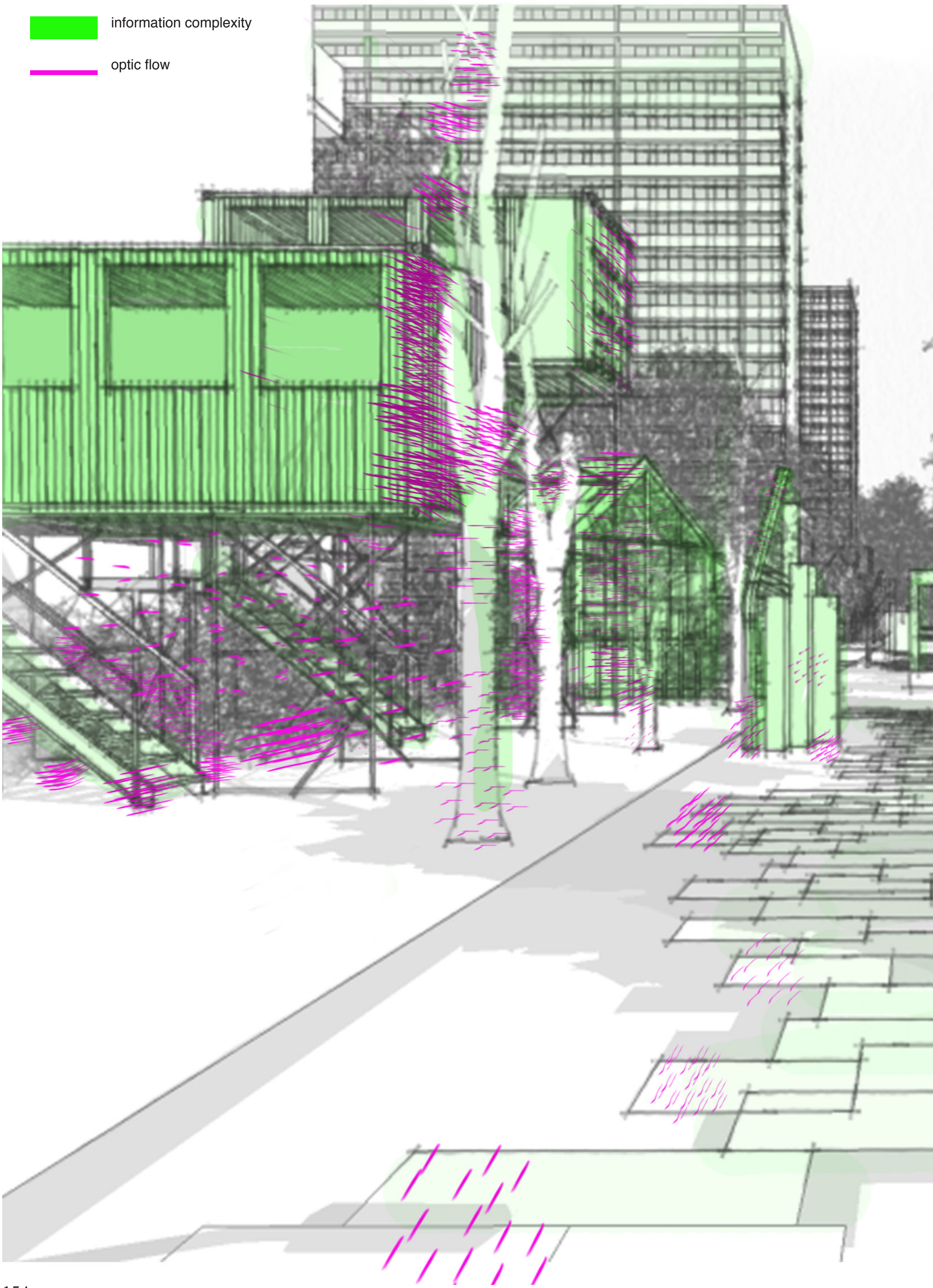
Medium interventions

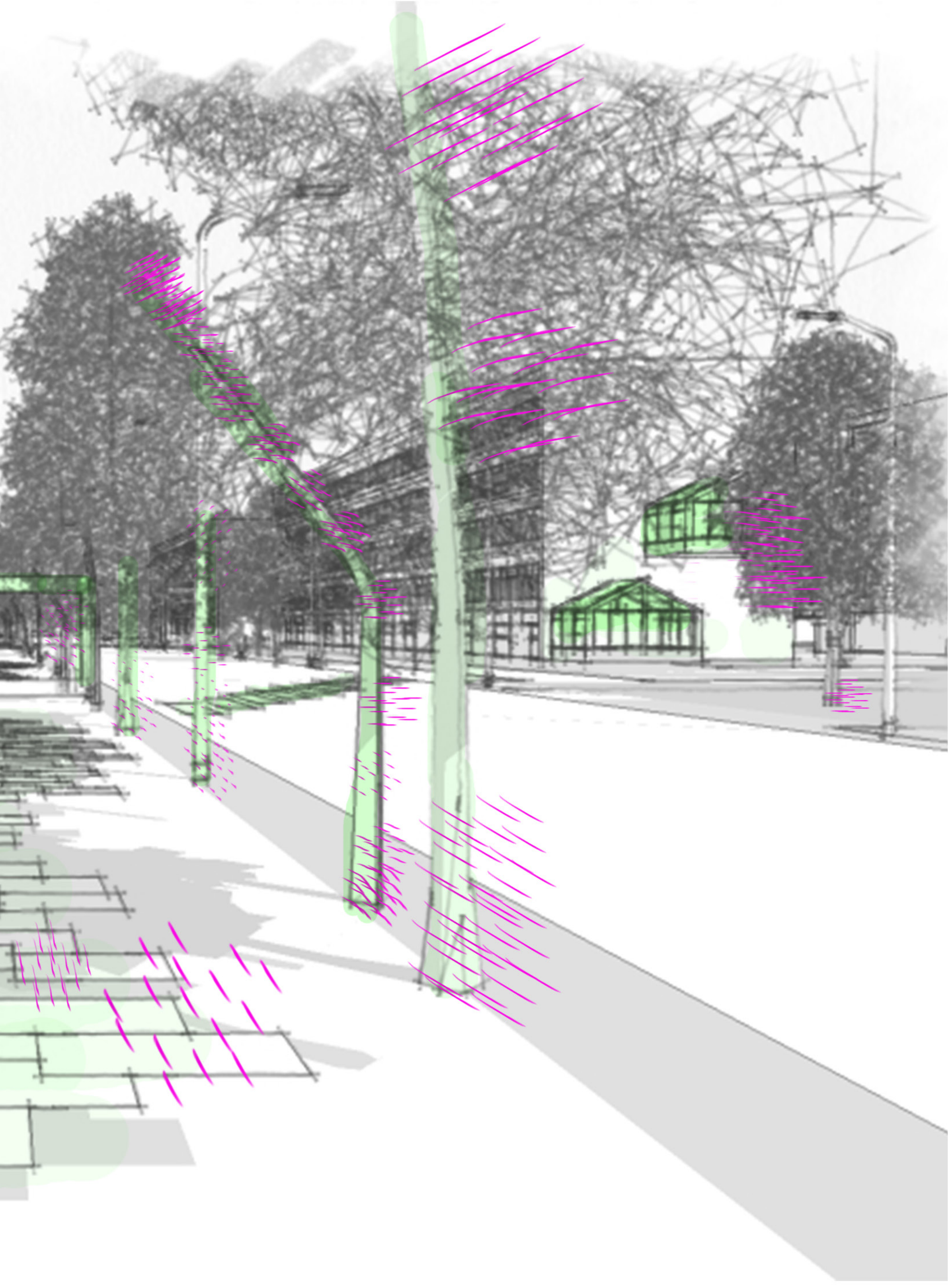
Variety in urban space, temporary volume complexity, dwelling type, environment transition, and direction of flow

Adding to the minimum version, more rigid interventions can include changes in the function of the urban space like a sports pitch, children's playground, communal garden, etc. Architectural volume complexity can be achieved by including small and temporary buildings that have a great impact visually. In this example, container units are added to the blind façades of large gallery flats to abrupt the static visual flow, and pointy-roofed communal greenhouses are placed strategically in the open, to create contrast with the larger blocks. Placing square screens in front of the greenhouses accentuates the contrasting scene.
To manipulate the user's visual flow, and to deviate from vanishing points, instead of the standard orthogonal parking lot, car "parks" are scaped that rearrange the car park-to-building entrance route. Scattering the car parks in the unused green also gives space for a sports pitch, which has the potency to use its caging as a bright mesh object that instantly increases the visual information complexity (due to its rapidly changing figure-ground relation). The sports pitch also gives the opportunity to place curvy benches and planters that are in line with the caging, and contrasting with the background flats.


pavement/
planting
urb.space
pavement
mesh
objects
bldg.
articulation
opt.flow
direction
fig_gr motion
spc_motion
urb_ details
urb_ spaciousness
urb_ buildings
arch_complexity
arch_details

Variant 2 optic flow

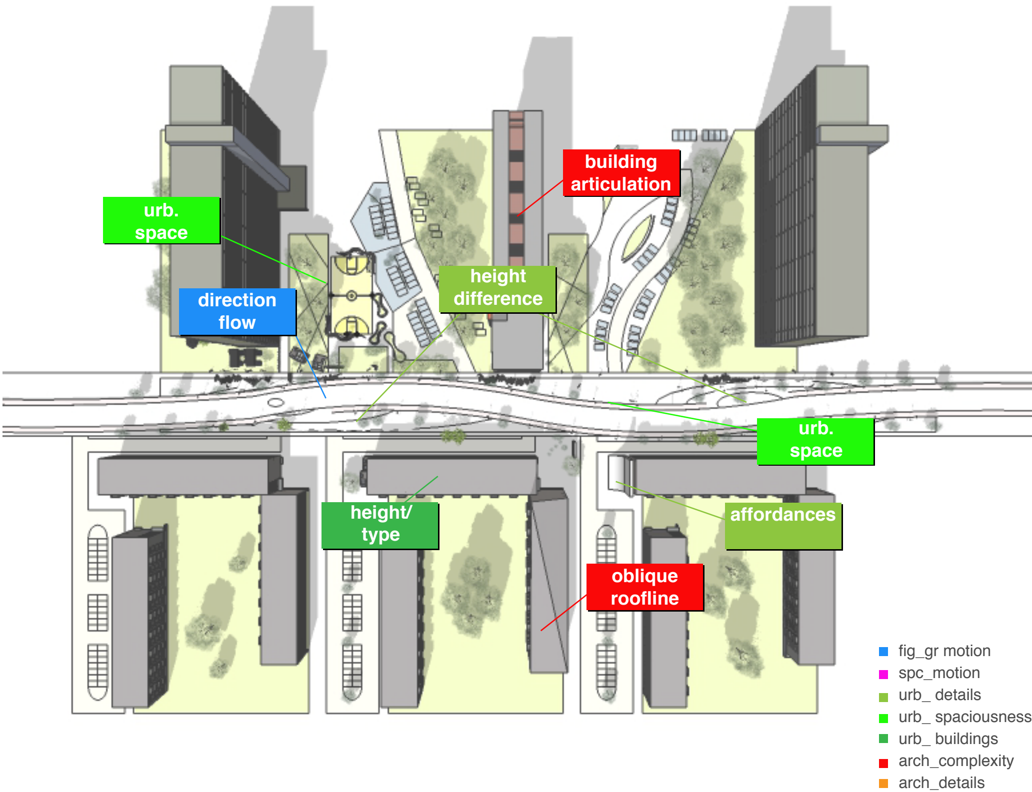




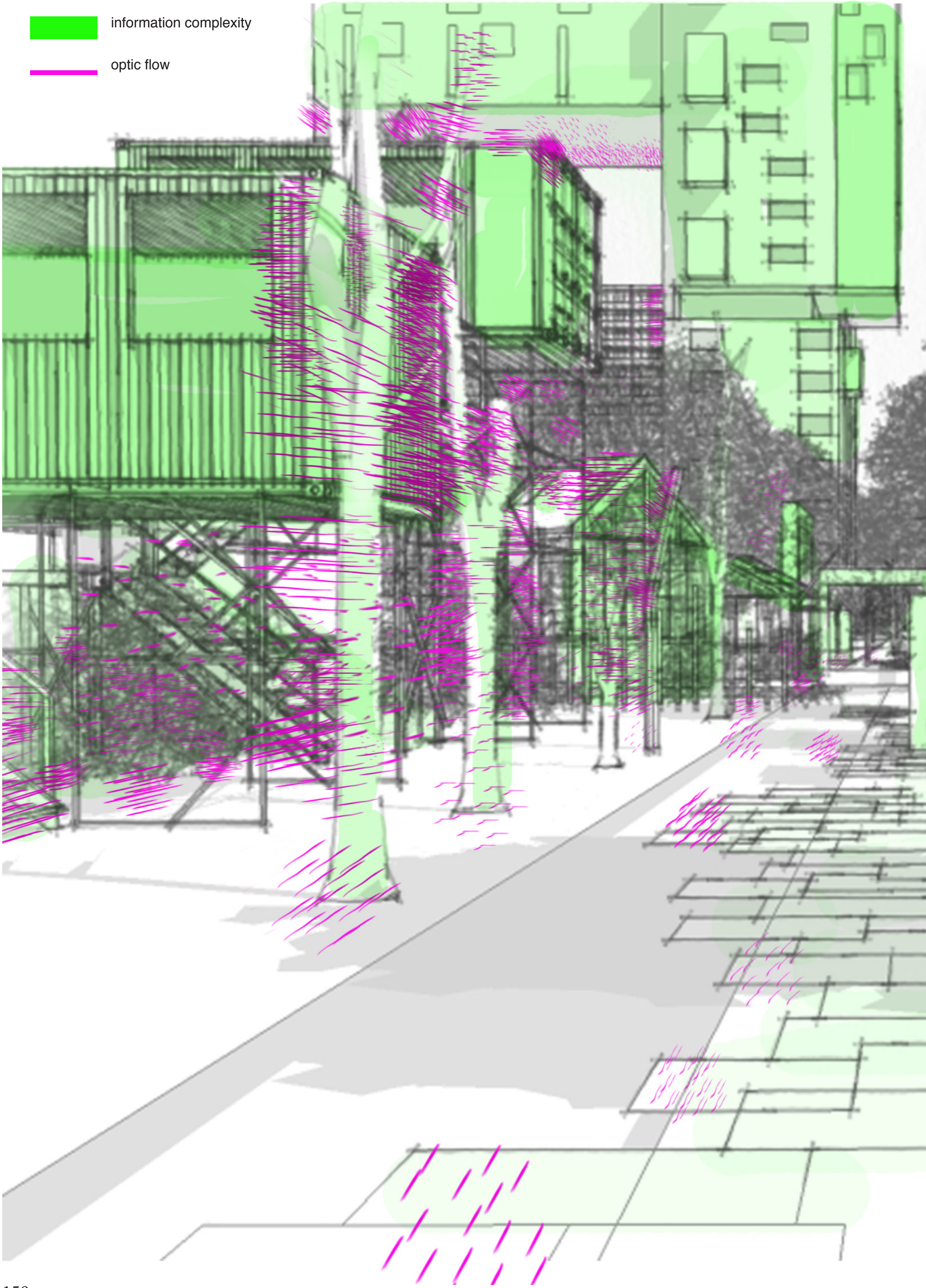
Rigid interventions

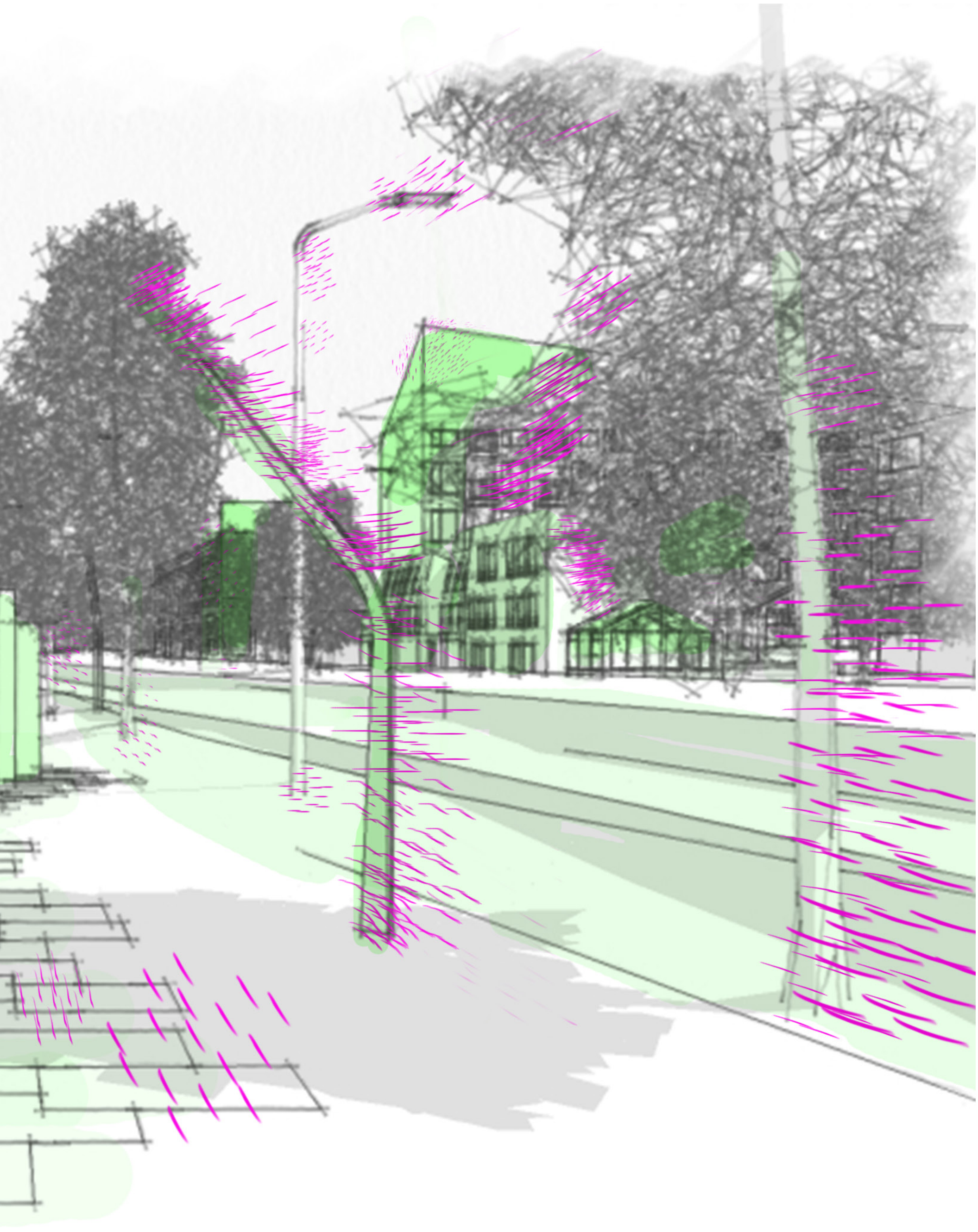
Building volume, building articulation, space types, added infrastructure, and raised terrain occlusion.

This variant adds new building volumes and details, building types, a present height difference, and infrastructural changes, creating more abrupt dynamic in the rhythm and direction of optical flow.
Curving the main access road emphasizes the sequential scene change, while simultaneously providing pockets along the walking route, adding to the urban complexity of types of spaces. Slightly raising the road creates occlusion in the view from the inner courts to the main road. Sloped curvy surfaces, in contrast with rectangular buildings sticking out from the background raises the overall information potency of the scenes and provides nuanced difference between the "here and there".


urb.
space
direction
flow
height
difference
building
articulation
urb.
space
height/
type
affordances
oblique
roofline
fig_gr motion
spc_motion
urb_ details
urb_ spaciousness
urb_ buildings
arch_complexity
arch_details

Variant 3 optic flow



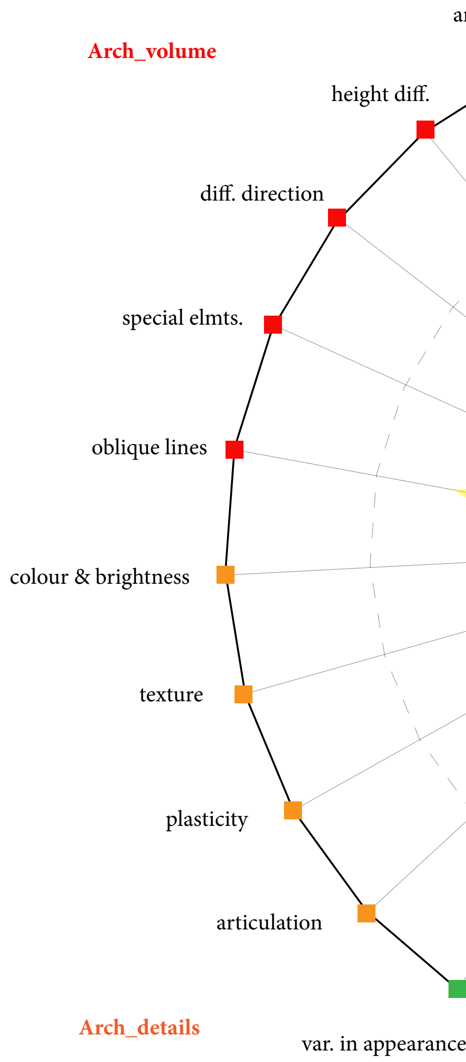


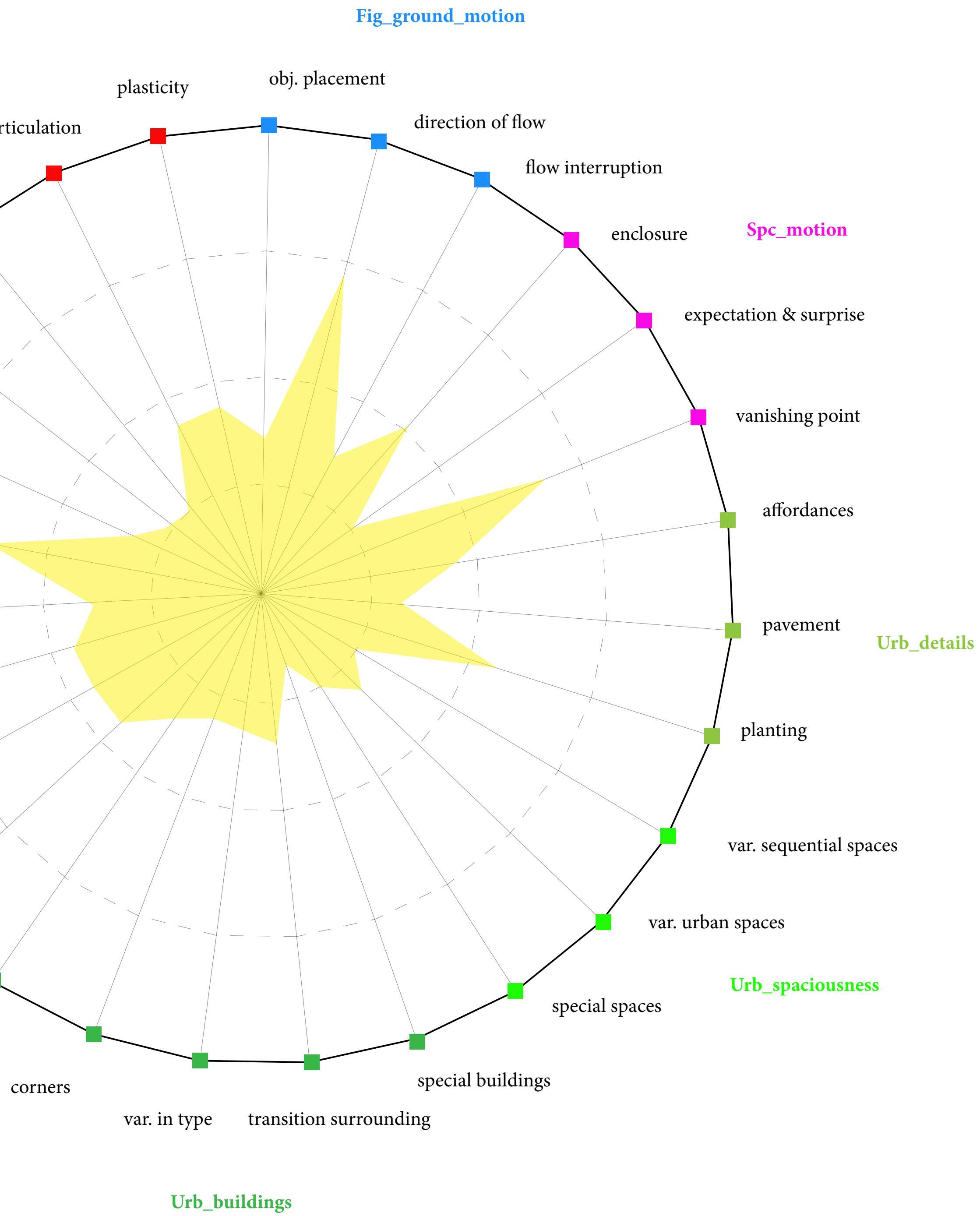
Rigid interventions - birdseye view

Example case: De Kamp, Nijmegen

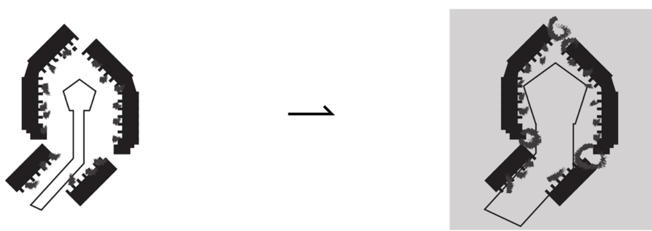
Example case: De Kamp – Nijmegen

De Kamp in Nijmegen is a perfect example of a typical 1980's "cauliflower" neighbourhood, which is characterised by its meandering angular structured main street (the root), adjoined by its cul-de-sac like residential courts, paths and courtyards (the heads or flowers). The angular roofs and use of oblique lines give the plan an organic appearance (direction of flow, vanishing points), while at eye-level the buildings are repetitive, creating monotonous scenes. The use of asphalt and concrete pavement and brick cladding make the scene visually messy. In general, the scenes provide little complexity in urban spaciousness and urban details. While the direction of flow is relatively complex due to angular streets and private front-gardens, the lack of variety in spaces abolish the element of expectation & surprise, and furthermore accentuate the blind low complex façades.

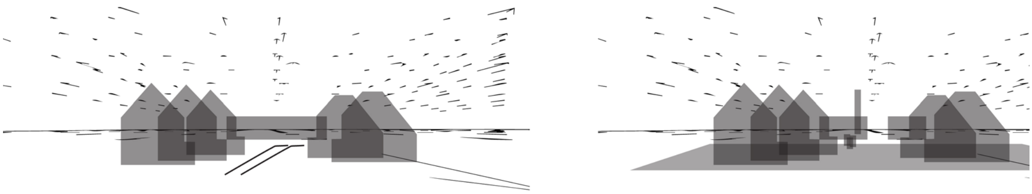




Fig_ground_motion
plasticity
obj. placement
rticulation
direction of flow
flow interruption
enclosure
Spc_motion
expectation & surprise
vanishing point
affordances
pavement
Urb_details
planting
var. sequential spaces
var. urban spaces
Urb_spaciousness
special spaces
special buildings
corners
var. in type
transition surrounding
Urb_buildings



From visual messy



to sequential coherence


Image capture: Sep 2017
© 2018 Google
Netherlands
Terms
Report a problem

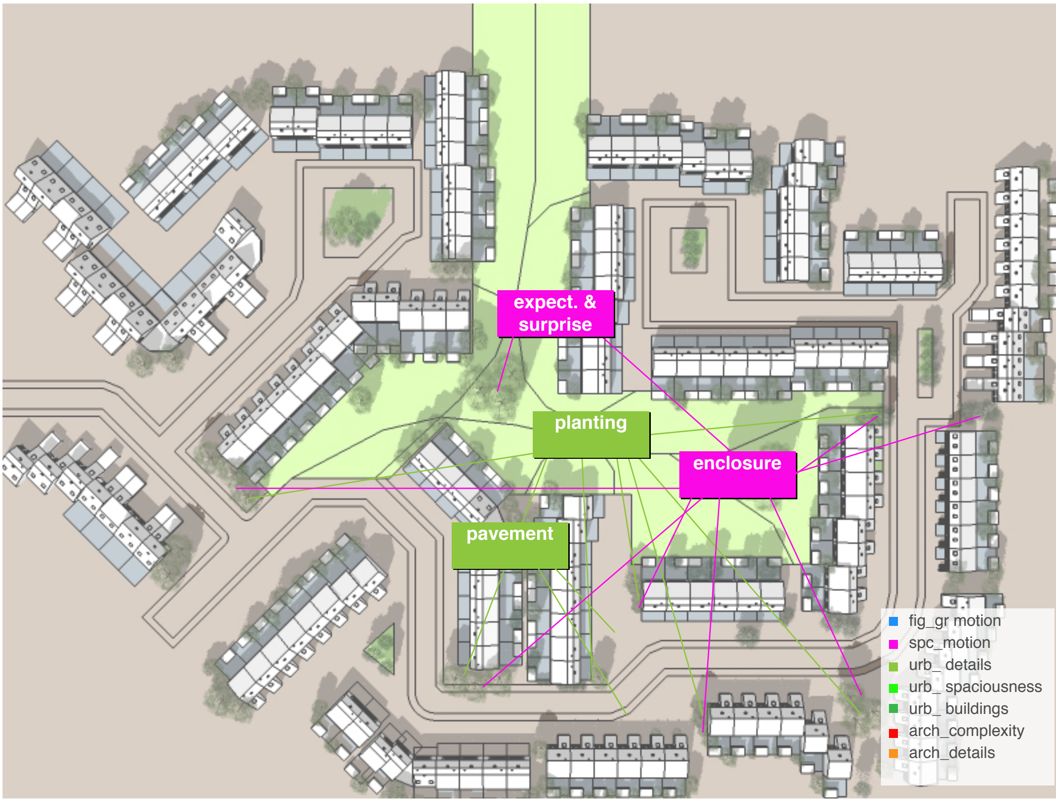
before

impression after

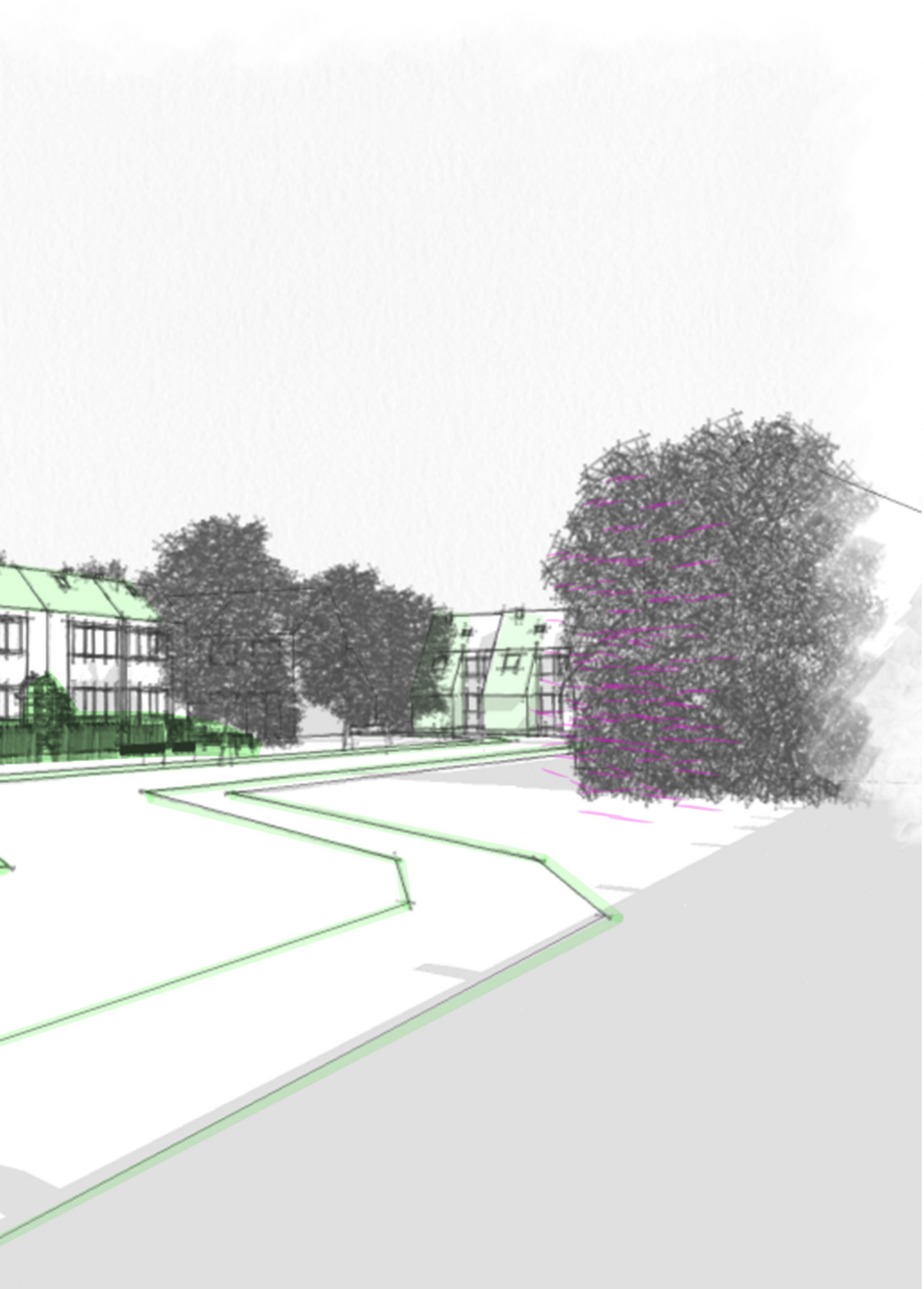
Minimum interventions

Coherent pavement, enclosure, occlusion, expectation & surprise.

Changing the pavement of the street and sidewalk to a similar paved texture not only gives a more coherent appearance with brick facades; it also eliminates the affordance that a large section of the street is reserved for driving. Furthermore, by simplifying the overall colours into the same tint can emphasize the green tones in high quality planting. Trees and planting can be used to create occlusion at blind façades, while taller trees in the centre courtyards create landmarks that stick out.


expect. &
surprise
planting
enclosure
pavement
fig_gr motion
spc_motion
urb_ details
urb_ spaciousness
urb_ buildings
arch_complexity
arch_details

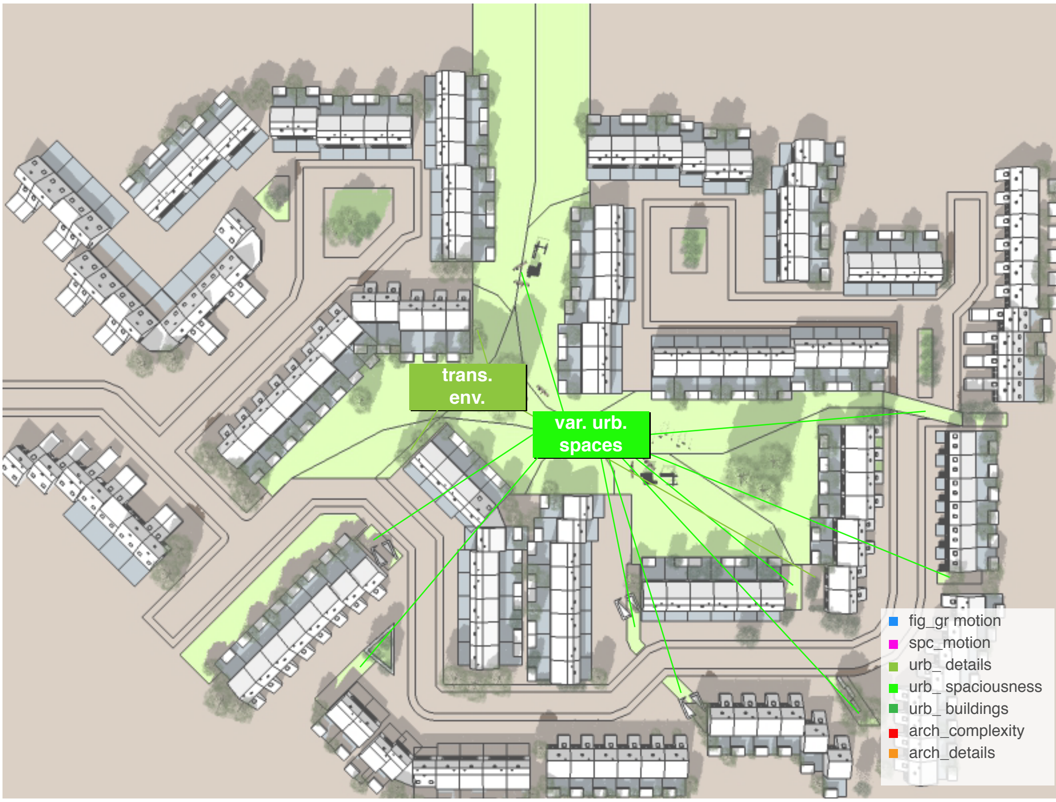

information complexity
optic flow



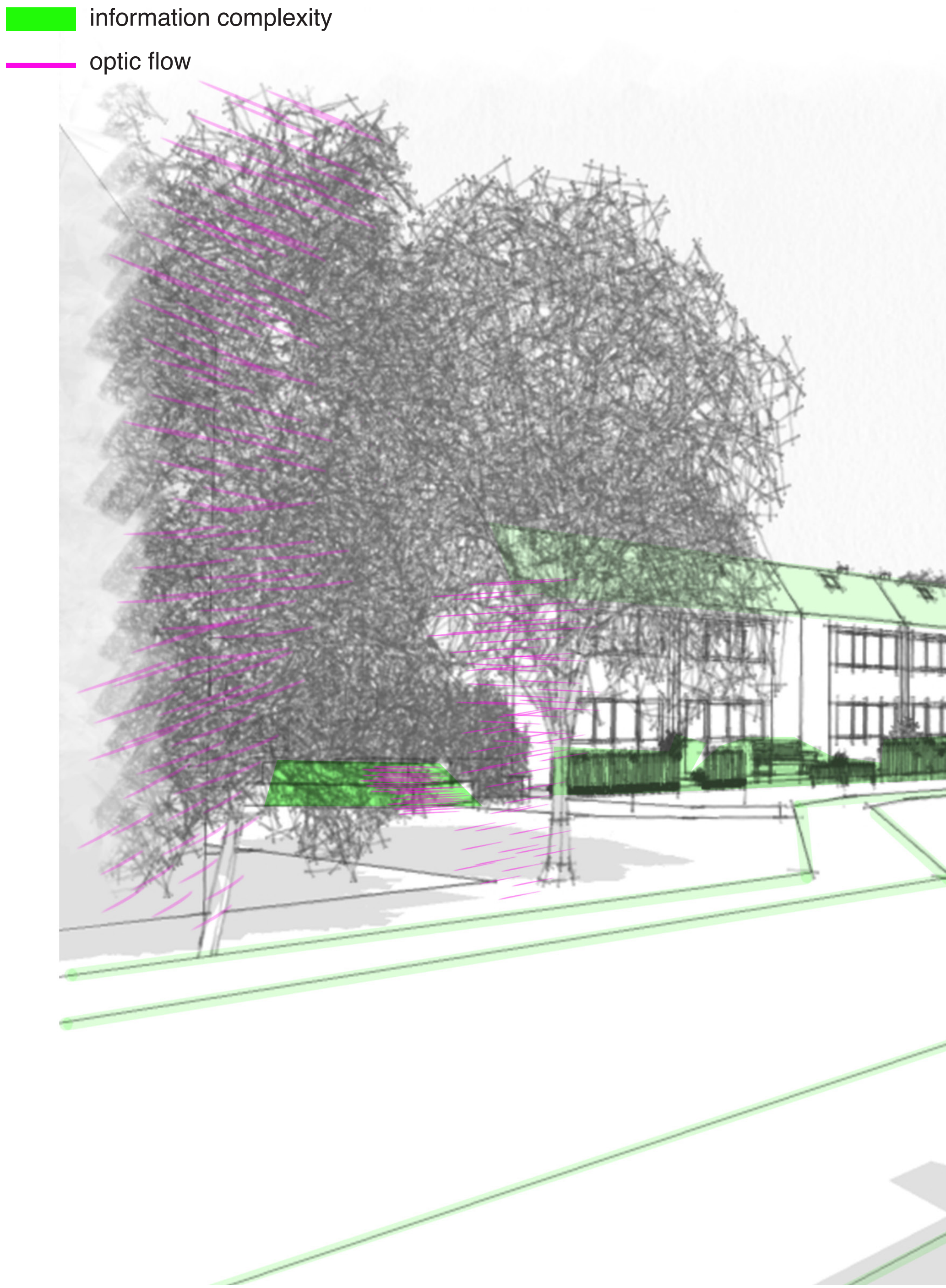
Medium interventions

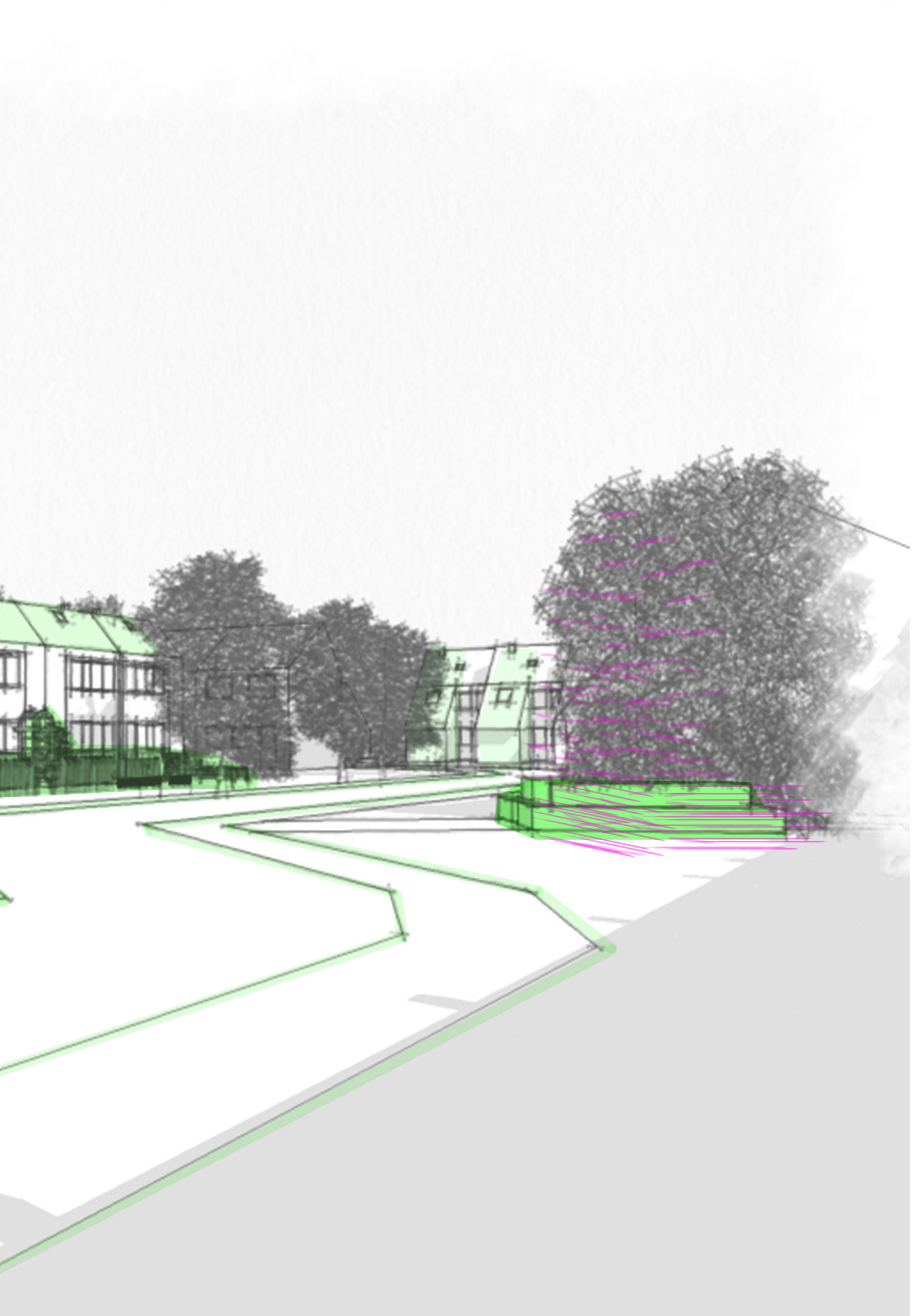
Pockets of spaces & environmental transitions

The spots where the observer meets blind façades are very low in sensory complexity, making it a serious problem in terms of visual perception. Changing these spots into small green and loitering pockets introduces a new function in the street while also creating new sequences. Extending the green areas into the street, where green elements are visible also raise the complexity in urban spaciousness.



trans.
env.
var. urb.
spaces
fig_gr motion
spc_motion
urb_ details
urb_ spaciousness
urb_ buildings
arch_complexity
arch_details

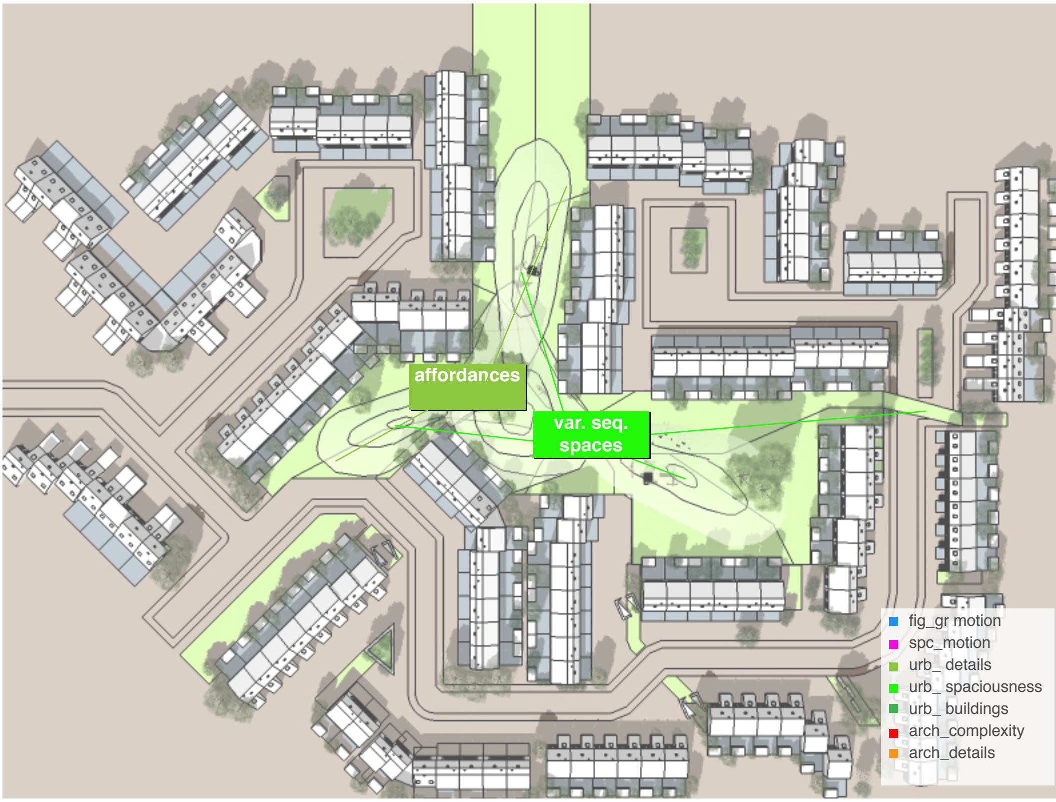

information complexity
optic flow

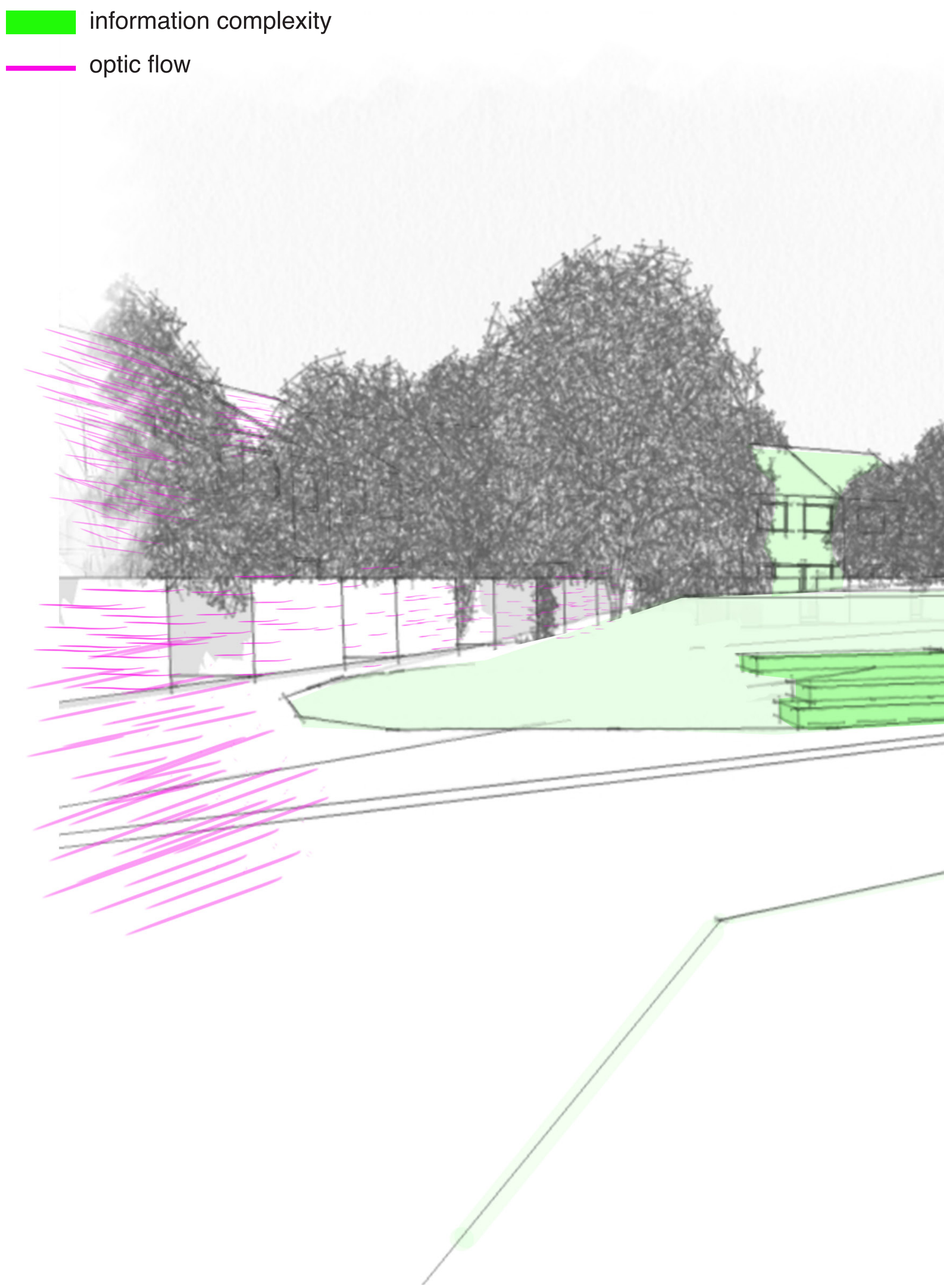


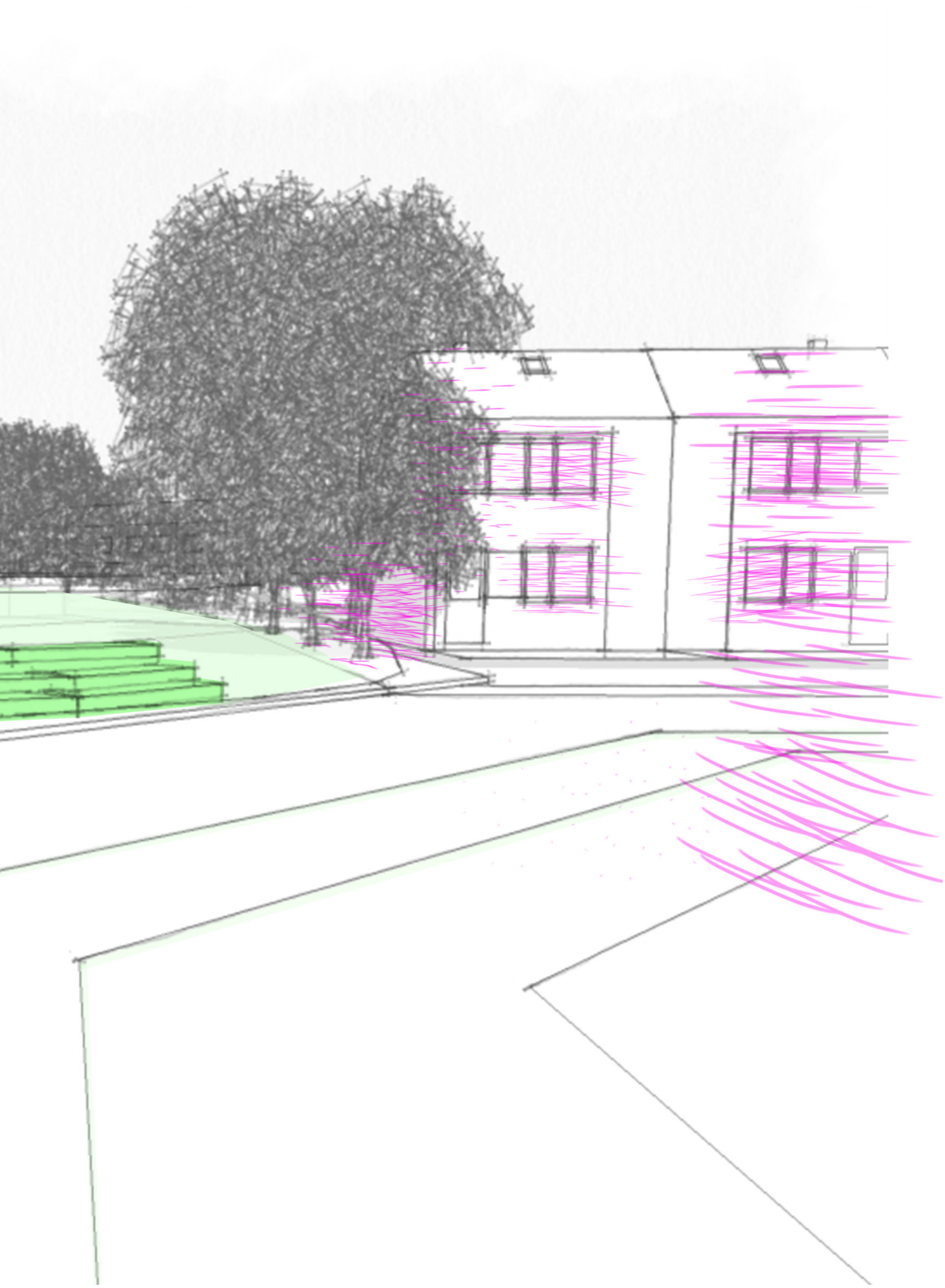
Rigid interventions

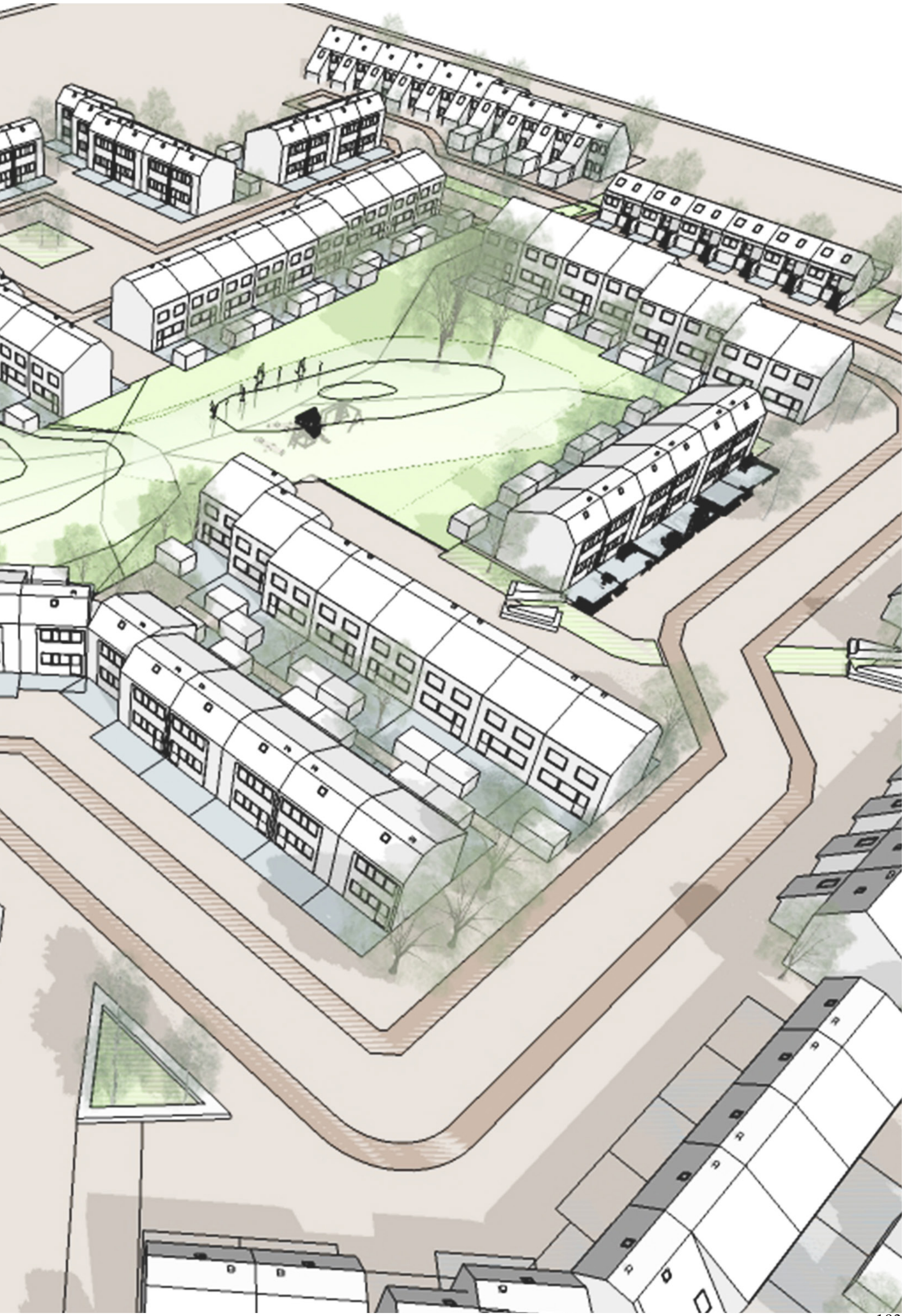
Height differences & affordances

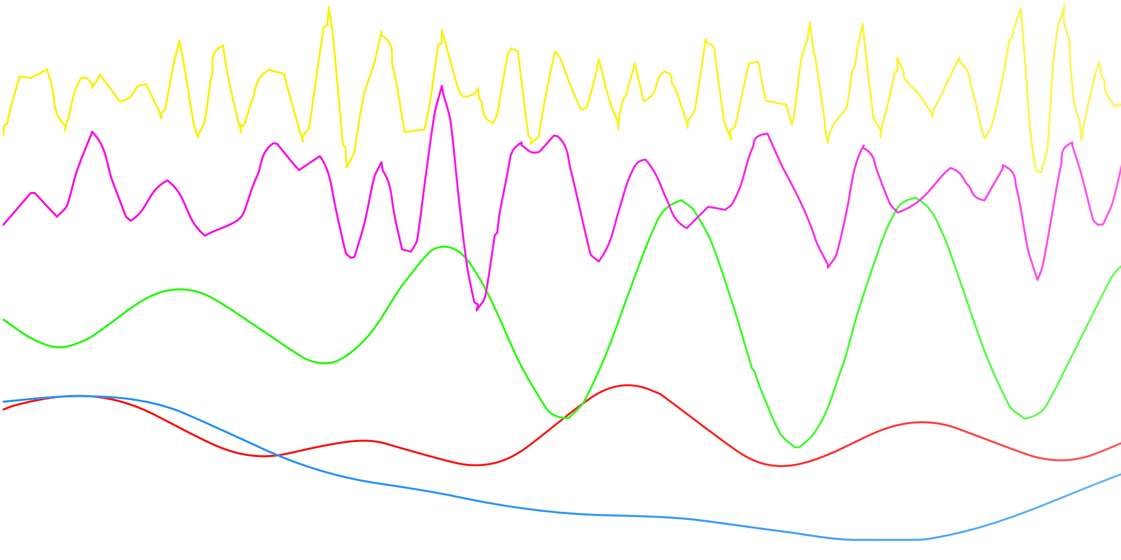
One of the qualities of Poptahof was that it provided vistas and glimpses to grassy and hilly slopes in the park. Because hills and height differences in urban environments are not that common in the Netherlands, it provides a good way of expressing change and complexity in the streetscape, while maintaining the calming effect of green. Furthermore, seasonal changes can accentuate the change (e.g. sunbathing in the summer and sledding in the winter). Cutting paths in slopes and hills accentuate the affordance of a path. Introducing new functions in the middle of the courtyard can increase human (or animal) flow, raising the visibility and alert perception of occasions.


affordances
var. seq. spaces
fig_gr motion
spc_motion
urb_ details
urb_ spaciousness
urb_ buildings
arch_complexity
arch_details


information complexity
optic flow







8. CONCLUSIONS

In the second chapter we had defined the following research question:

*Which **spatial elements** are essential in influencing our visual **perception** of urban environments, and how can we explicate and express these elements in urban design?*

with the following sub-questions:

Can we find patterns of gaze behaviour, change in EEG frequency bands, and gazed elements?

If so, when and how do these patterns occur, and what specific attributes do they have in common?

How can we express these attributes in urban design?

The following paragraphs address the sub-questions sequentially in order to give a concluding answer to the main question.

Patterns of gaze behaviour, EEG frequency bands, and gazed elements

Despite the number of participants being too low to generalize findings, results from the ERSP-video analyses have shown reoccurring patterns of gaze positions, eye movement behaviour, concentrations in EEG frequency bands, and specific spatial elements that occur in the scenes. Concentrations in the alpha band occur while scanning the environment with rapid scanning motions that follow the contours of the space, following edges, lines, or paths and relatively simple elements in terms of cognition. Frequency peaks in the beta band occur when looking at shapes that are deviant from the scene, objects that stand out, or surfaces that need a higher level of cognitive processing, while signs, distant elements, or moving elements such as cars or people (referred to as occasions) raises concentrations in the gamma range.

Patterns of specific attributes in information potency, and change in optic flow

Classifying the resulted spatial elements from chapter seven into a level of "alertness" made it obvious that these elements can be further dissected into their level of complexity and sensory information potency (Steffen, 1989). The more unpredictable the phenomenon is, the greater the potency is to acquire and process new knowledge. With our visual system set to track changes and discover new information in the environment, perception involves both information that is partly new, unpredictable, and unexpected, and partly known, expected, and predictable. Interestingly, the spatial elements from chapter seven have in common that they are evoked from multiple spatial "events" in a short time interval. In short, alert visual perception goes to where the sensory information potency is high and the optical flow changes rapidly. However, the complexity should not be too great: the environment must encompass surprises, but must also be clear in order to keep a general overview. The need for information variety thus is not unlimited. Too much sensory impulses in a short period of time leads to overstraining and discomfort. For designing regarding our visual perceptual system it is thus essential to find the ideal balance between the existing context, users, potential sensory information, complexity, and the relative motion that occurs when moving through spaces. In order to create harmonious urban environments, the tension field of architectural- and urban complexity, and the complexity of relative motion must be in balance.

Balance in architectural & urban complexity, and complexity of relative motion

To answer the main question, spatial elements, or better yet, spatial *events* if we account the dynamics in the optic flow, that are high in their complexity of sensory information and information potency are related to a more alert perception. This however does not mean that spatial elements with low complexity are less relevant in influencing the visual perception. In contrary, the contrast (or balance) between high- and low complexity in sensory information of spatial elements can be used in urban design to emphasize what the specific design goal for a specific urban scene is. Depending on the design goal and context, we should be aware of what we design in terms of sensory information and complexity, to avoid visual nuisance or sensory deprivation.

REFLECTION

As human beings we are always (sub)consciously perceiving and interacting with our environment. As designers therefore, we try to design healthy environments that not only look good aesthetically, but also function in a technical and sustainable way. Consequently we discuss social behavior and centralize the “human scale” in our designs, but we somehow tend to neglect the important fact in *how* we actually perceive our environment in cognitive and psychological terms. By making this perceptive process, what we see, hear, smell, feel and more importantly, what our mind makes of it, more tangible, we can achieve a better understanding how the built environment affects the body and mind.

From biased methods to objective perceptions

The current existing methods to study liveable environments however are based on two biased methods (van Dorst, 2005). The first is measuring perceived liveability. The problem with this method is the cognitive bias of every individual and the sub-conscience influence of the physical environment on well-being. A simple example; users of a shopping street are not always aware of the trees present, yet benefit by the stress reducing effect of green (Kaplan & Kaplan, 1989). The second method is called presumed liveability; here we presume all kind of influences on the well-being of people by qualities of the environment, although we can not measure any cause-effect relations. Cleaner streets were presumed to be more liveable; the correlation is *there*, and yet no cause-effect relation is proven (van Dijk & Oppenhuis, 1998). New technology can help us here to measure perceptions more objectively in relation to physical well-being. By relating this data to the built and natural environment we can evolve from a biased way of measuring liveability to a more inter-subjective way of measuring. On societal level, this dichotomy can lead to a negative spiral of a neighbourhood its image, which in turn can lead to segregation, promoting a biased perceived liveability.

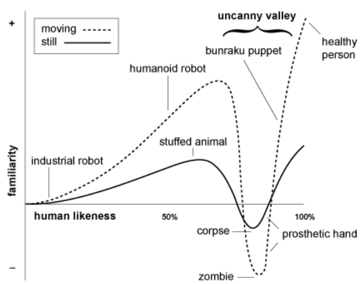
Using eye-tracking and EEG sensors therefore seemed a valid combination to initiate objective research on design, and how we perceive our environments. However, even though recent studies within the field of urbanism or environmental psychology exist, the analysis methods were not clear. Therefore, the initial phase of this research contained a series of methodological experiments and test-runs to get familiar with the acquired gear, to establish an adequate workflow,

Existing research, replicability & generalizability

and most importantly, to know what the possibilities and limits are, and how to interpret collected data. Similar research (using EEG) had already showed results (Mavros et al, 2016), but were more about general findings rather than specific spatial or design elements. Nevertheless it motivated to try new approaches combined with qualitative research methods.

Commercial-grade equipment

A substantial drawback in the research is that (commercially) available EEG devices are used to collect data. EEG research is usually done in labs, using clinical tools, with a team of expert lab technicians and data-analysts. Even though, there were studies available that showed correlation with insights, and showed positive results in the field of brain-computer interface, initially the data was interpreted with a pinch of salt. After adjusting the initial data collection and analysis methods, results were more trustworthy, indicating interesting patterns of tracked gaze positions and EEG frequencies.



Uncanny-valley (Mori, 1970)

A second limit of this research is that, after adjusting to a workable method, data consisted of the visual perception of 2D videos rather than the perception of real environments, or in Gibson's terms, the visual world. Even if we would do the same experiments in a VR-setting, the "uncanny valley" effect (Mori, 1970) variant of environments could evoke very different outcomes. In order to have meaningful results, the VR setting needs to be hyper-realistic to capture the more detailed information complexity (such as texture).

As is mentioned before, the low n, and two urban environments account the research to be non-generalizable to different user-groups or urban environments. In this extent further research needs to be done with different target groups, and different urban environments.

The outcomes are generally in line with the body of knowledge and theory on visual perception. However, the interesting potential in this research method is that it can provide substantial proof for more nuanced differences of objects and complex PQA's in relation to their spatial-, or visual context; objects and shapes and what we make of them e.g. slim trees as a shape that raises alertness vs. large trees with big green crowns that provide calming reactions; or the perception of gestalt principles in the visual world, however in order to achieve better validity, extended research is needed, replacing the commercial grade equipment with clinical or medical gear and research methods.

Analytical or evaluative guideline, rather than linear tool

The research focuses solely on visual perception, meaning that the spatial-perceptual complexity tension field is primarily based on visual perception. In urban design however the design goals or objectives are far more "wicked", comprising multiple other (physical, social, or economic) factors and layers, and require complex lateral design thinking. In this sense, the complexity tension field cannot be used as a linear design tool to achieve good design, but should rather be referred to as an analytical (from the start) or evaluative (in the process) guideline in *addition* to keep the design in balance and avoid visual deprivation or visual nuisance.

While the outcome allows urban designers to distance from a conventional technical, social, or picturesque approach, and see the environment differently in terms of affordances, sensory information complexity, and optical flow, the aesthetic quality of good design, or, beauty, still remains subjective and a responsibility of designers to incorporate it as a function in design.

REFERENCES

Alexander, C., Ishikawa, S., & Silverstein, M. (1977). *A pattern language : Towns, buildings, construction.* New York: Oxford University Press.

Aspinall, P. Mavros, P. Coyne, R. et al. (2013) *The urban brain: Analysing outdoor physical activity with mobile EEG.* Br J Sports Med. Published online March 6 2013.

Berlyne, D. E. (1971). *Aesthetics and psychobiology* (The Century psychology series; The Century psychology series). New York: Appleton-Century-Crofts.

Cernea, D., Kerren, A., & Ebert, A. (2011). *Detecting insight and emotion in visualization applications with a commercial EEG headset.* SIGRAD 2011 Conference on Evaluations of Graphics and Visualization-Efficiency, Usefulness, Accessibility, Usability,(Stockholm, Sweden) (pp. 53–60).

Ching, F.D.K. (1979). *Architecture: form, space & order*. New York, Van Nostrand Reinhold.

Coeterier, J. F. (2000). *Hoe beleven wij onze omgeving?: Resultaten van 25 jaar omgevingspsychologisch onderzoek in stad en landschap.*

Cullen, G. (1971). *The concise townscape*. New York: Van Nostrand Reinhold Co.

Dalgleish, T., & Power, M. (1999). *Handbook of cognition and emotion.* Chichester etc.: Wiley.

Frisby, J. P., & Stone, J. V. (2010). *Seeing : The computational approach to biological vision* (2. ed.). Cambridge, Mass.: MIT Press.

Gibson, J.J. (1950). *The Perception of the Visual World*. Boston, The Riverside Press.

Gibson, J.J. (1979). *The Ecological Approach to Visual Perception*. London, Lawrence Erlbaum Associates.

Gifford, R. (2002). *Environmental psychology : Principles and practice* (3th. ed). Colville, WA: Optimal books.

Goldstein, E. B. (2002). *Sensation and perception* (6th ed.). Australia: Wadsworth-ThomLearning.

Kaplan, R., and Kaplan, S. (1989). *The Experience of Nature. A Psychological Perspective.* Cambridge: Cambridge University Press.

Lee Y-Y, Hsieh S (2014) Classifying Different Emotional States by Means of EEG-Based Functional Connectivity Patterns. PLoS ONE 9(4): e95415.

Lynch, K. (1960). *The image of the City*. Cambridge: The MIT Press

Lynch, K. & Rivkin, M. (1959). A walk around the block. *Landscape*, 8, pp. 24-34.

Malnar, J. & Vodvarka, F. (2004). *Sensory design.* Minnesota: University of Minnesota Press.

Nasar, J.L. ed. (2008). *Environmental aesthetics. Theory, research and applications.* Cambridge: Cambridge University Press.

Nijhuis, S, Lammeren, R van & Hoeven, FD van der (eds.) (2011). *Exploring the Visual Landscape. Advances in Physiognomic Landscape Research in the Netherlands*. Amsterdam: IOS Press (ISBN 978-1-60750-832-8)

Mavros, P., Austwick, M.Z. & Smith, A.H. (2016). Geo-EEG: *Towards the Use of EEG in the Study of Urban Behaviour*. Applied Spatial Analysis (2016) 9: 191.

Meiss, P. v. (1992). *Elements of architecture : From form to place.* London: Van Nostrand Reinhold

Mori, M. (1970). *Energy*, 7(4), pp. 33-35. Translated by Karl F. MacDorman and Takashi Minato

Oude Bos, D. (2006). *EEG-based emotion recognition-The Influence of Visual and Auditory Stimuli*. Capita Selecta (MSc course), University of Twente, 2006

Prak, N.L. (1979). *De visuele waarneming van de gebouwde omgeving*. Delft, Delft University Press.

Priniakanis, E.M. & Sükür, M.D. (2015). *The 2C, Creative and critical thinking: a reflection upon the Urbanism MSc programme at TU Delft*. Unpublished manuscript. Delft: TU Delft

Portugali, J. et al. (2012). *Complexity theories of cities have come of age : An overview with implications to urban planning and design* (Springer complexity; Springer complexity). Berlin: Springer.

Rifkin, J. (2011). *The third industrial revolution: How lateral power is transforming energy, the economy, and the world*. New York: Palgrave Macmillan.

Sawant & Jalali (2010) *Detection and classification of EEG waves,* Oriental Journal of Computer Science & Techonolgy. 3 (1) pp. 207-213

Schacter, D. L., Gilbert, D. T., Wegner, D. M., & Hood, B. M. (2016). *Psychology / Daniel Schacter, Daniel Gilbert, Daniel Wegner, Bruce Hood* (Second European edition.). London: Palgrave Macmillan

Steffen, C. (1981). *Psychologie van de waarneming.* Delft, Technische Hogeschool Delft.

Stolk, E.H. (2015). Een complex-cognitieve benadering van stedebouwkundig ontwerpen. *A+BE: Architecture And The Built Environment*, *5*(8), 1-458.

Thiel, P. (1997). *People, Paths, and Purposes: Notations for a participatory envirotecture.* Seattle: University of Washington Press.

Zeki S. (1993) *A Vision of the Brain*. Oxford, Blackwell Scientific Publications