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Mobile Eye Tracking in Landscape Architecture: Discovering a New Application for Research on Site

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Additional information is available at the end of the chapter

Abstract

This chapter presents the process of establishing a laboratory for mobile eye tracking focussing on real-world, open-space environments within the field of landscape architecture at the Osnabrück University of Applied Sciences (D) as well as the latest results from the feasibility study 'Point de Vue', which defines the basis for qualitative interaction analyses in landscape architecture. Eye tracking is a tool that has been used extensively in the domains of psychology, marketing, usability and user experience in remote and mobile applications, but has rarely been used in real-world open spaces because of technical limitations. To check the possibilities of mobile eye tracking as a new application in open spaces, several exploratory tests and a feasibility study with long-term experiments have been carried out in urban settings as well as in world famous parks such as 'Grosser Garten' in Hannover (D) and 'Stourhead' in Wiltshire (GB). These experiments have shown extraordinary results that enable us to use mobile eye tracking as a new tool in open space research to gain knowledge about how people act, react and interact in open-space environments. Being able to see and understand what catches one's eye and the response to it will be a guide to better design.

Keywords: historic parks, landscape architecture, mobile eye tracking, usability, landscape analysis, human behaviour, urban planning, open space design, user experience, UX, Stourhead, Grosser Garten, Point de Vue, interaction, common shared experience (CSX), path-related interaction protocol (PrIP), eye tracking collective (ETC.la), qualitative interaction analysis

1. Introduction: What do you really see?

How interesting would it be if we could look through someone else's eyes and get directly inside their mind? The movie Being John Malkovich [1] gives an idea of how it would be

to see the world through the eyes of another person and get a deeper understanding of their actions and even their thoughts. Mobile eye tracking (**Figure 1**) is able to realise this to a certain extent and gives us first insights. Therefore, it is broadly used to study human behaviour in marketing and usability research, and it is a unique method for documenting instant interaction with a stimulus. What do people see? How do they act or react to what they see? What makes a person interested in or spend time at a specific place or makes them leave when bored [2]? All these questions were important to guide this research in landscape architecture and to understand the difference that mobile eye tracking can make if used as a tool. The basic question is whether this new mobile technology can provide the possibility of being an invisible companion to a normal visitor to an open space and to understand his behaviour and reactions. Besides several content questions, such as the testing of design concepts or the identification of 'good places', the evaluation of its feasibility was the main focus. Crucial for that was the development of experimental as well as evaluation methods.

The acquired knowledge is the sum of results (answering the research questions), insights (based on the broad documentation of interactions) and a general understanding of the research area through spending time in the landscapes and interviewing visitors. The essential result and a basis for further studies is the developed, experimental method 'common shared experience' (CSX) which allows an unobtrusive look through the eyes of the subject. The verbal mood map (VMM) as well as the path-related interaction protocol (PrIP) were developed as evaluation methods. These detected salient spots for profound analysis processes in the research area.

Anticipating the results of the research project 'Point de Vue' (see Section 4), it can be said that visitors to historic gardens and parks behave differently than the planner predicted and that even those historic gardens are changing over time. Interaction analyses not only confirmed traditional viewpoints in the Stourhead landscape garden ([3], p. 217) but partially defined new viewpoints and also landscape windows, which are subtle lookouts.

Figure 1. Mobile eye tracking in Stourhead landscape garden. National Trust, Steve Haywood (2016).

2. No future without roots

The 'Eye Tracking Collective' (ETC) is an interdisciplinary research association established at the University of Applied Sciences in Osnabrück (D) in 2015. Founded and coordinated by the authors of this chapter, the main issues are international research projects and academic teaching. The disciplinary section in the fields of landscape architecture and urban planning is the 'Eye Tracking Collective.landscape architecture' (ETC.la).

After first getting into contact with mobile eye tracking research through Prof. E. Fujii (Chiba University, Japan), the group started with the overall support of the Faculty of Agricultural Sciences and Landscape Architecture to focus on the research of human behaviour in real-world environments under non-laboratory, outdoor conditions to get as close as possible to a realistic insight. Two master theses started the process and compiled essentials for eye tracking research in landscape architecture [4] and tested the capability of mobile eye tracking in open-space research [5]. A next step was to discuss research approaches within the discipline of landscape architecture [6] and with other practitioners and scientists working in other complex, real-world environments.

After the ETC.la was established and equipped with a mobile, outdoor lab for field studies, the first study 'Point de Vue', funded by the 'Sievert Foundation for Science and Culture, Osnabrück' led by Prof. Dr. Hans-Wolf Sievert, enabled a jump from small scale to large scale and the development of new methods [7]. One of them, the 'Common Shared Experience' (CSX), is described in the following chapter. The Sievert Foundation supported this research investigating the application possibilities of mobile eye tracking in landscape architecture. 'Point de Vue' aimed to check whether mobile eye tracking was a proper, on-site research application in open spaces and defines the basis for future qualitative interaction analyses in landscape architecture.

3. Technical aspects of mobile eye tracking and method combinations

The eye tracking glasses (ETGs[1]) consist of a scene camera which films nearly all of the subject's visual field and overlays it with an infrared-based measurement of the pupil's position to produce a gaze video. Eye movements are measured at a frequency of 60 Hz by two infrared cameras implemented in the spectacle frame [8].

It works together with a smartphone recording unit (**Figure 2**) and therefore provides virtually unaffected mobility to the subject. This is fundamentally important for field studies ensuring a high ecological validity. The individual gaze videos are assembled and evaluated by a special software for educational and scientific use (BeGaze 3.7), so that researchers can review and thereby understand what the subject is doing and get insights into why the subject is doing

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[1]Version: ETG 2w by Senso Motoric Instruments (SMI).

Figure 2. ETG and smartphone recording unit. Detlef Heese (2017).

it. In addition, the sounds of the environment and the subject's conversations are recorded so that gaze videos can be regarded as a documentation of a multi-sensory experience.

Made for real-world environments and meanwhile applicable under sunny weather conditions, ETGs measure the durations and spatial distributions of the eye's fixations. The scene camera additionally documents the surrounding conditions with its overall atmosphere and disturbances as well as the subject's movement, sounds, utterances and other interactions. With these approaches, it is possible to analyse the subject itself, the object and the interaction between both. The possibilities of qualitative and quantitative analyses and interpretations of these massive datasets will be explained in Chapter 4 by reference to small scale, exploratory tests and the feasibility study 'Point de Vue'.

The outdoor lab (**Figure 3**) is also a part of the technical equipment for mobile eye tracking trials. First tests showed a necessity of having an obvious start and endpoint, which unobtrusively fits into the environment but with an appealing character for potential subjects. A weather-resistant tent with foldable furniture as a workspace for the researcher and room for information and ETG setups proved to be appropriate equipment.

Figure 3. Outdoor lab in Stourhead. ETC.la (2017).

Besides mobile eye tracking as a research method in itself, there is a need to combine it with various other methods because 'eye tracking can't answer all questions ([9], p. 97)'. The inter-relationships between complex research questions in disciplines like user experience (UX) or usability and a recommendable mix of methods were described, inter alia, by Bojko [9] and Holmquist et al. [10].

Figure 4 describes a combination of methods utilised in the fields of applied research where collected data can be separated into two domains: verbal and technical data. The technical data is considered as passive because it measures the body's responses, whereas verbal data always requires the spoken word of the subject or observation skills of the researcher. Thus, verbal data collection as described in **Figure 4** always has constraints in its ability to express or to observe something. Well-discussed method combinations supporting eye tracking studies are think aloud (TA) or retrospective think aloud (RTA) protocols [9, 11], which both have their individual side effects on data quality or ecological validity. The ETC.la method of dealing with this is the CSX. Subjects are not separated from the group they arrived with in the park or in the research area. Subjects are generally not given a task or a predetermined route to follow. Instead, subjects are asked to spend as much time as they want and are not limited in movement. Subjects tend to behave normally after the first few steps in an interesting, impressive and often cognitively demanding park such as Grosser Garten or Stourhead and this is what the CSX aims for. Examples for normal subject behaviour are the reading and writing of private messages on mobile devices, children running, playing or climbing on trees or subjects spitting on the ground without feeling caught in the act (although they are), to name just a few.
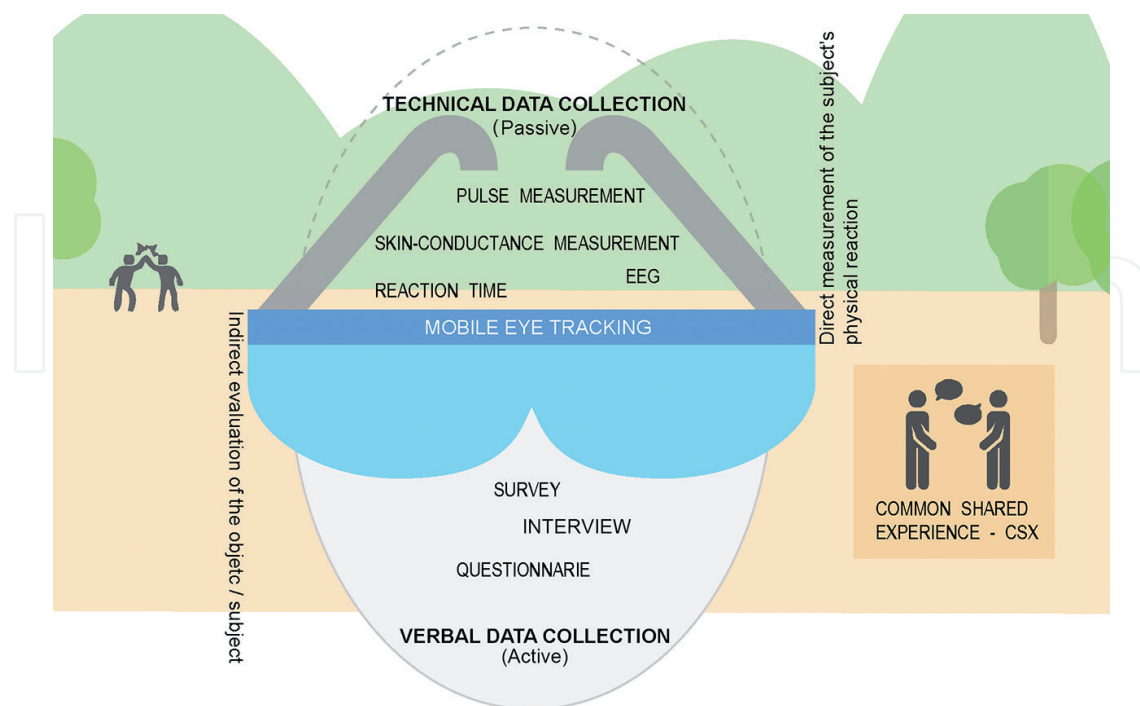

Figure 4. Mix of methods. ETC.la (2017).

With verbal and technical data collection, it can be assumed that ETG is a beneficial tool for real-world research with a high demand on ecological validity because they both provide and combine gaze videos with documented auditive and visual signals beside measured eye metrics.

4. Mobile eye tracking in landscape architecture

Mobile eye tracking is not a new technique and is frequently and standardly used in medicine, psychology, usability and UX or disciplines such as reading research. All of these different eye tracking applications have their justifications or origins in the endeavour to heal or understand humans or to improve a product, meaning an increase in sales figures. Both have a measurable positive effect on public health or economy. Another aspect of eye tracking is that it is usually applied in controlled environments with a defined group of subjects to achieve valid results and that the majority of studies deal with stationary (remote) eye tracking. This is because, beside other reasons based on the individual research design, data collection and analysis can be processed standardised or even automated.

However, landscape architecture has different demands on generating scientific knowledge. Basically, there are not many eye tracking researchers in natural or urban environments and only a few of them conduct mobile eye tracking trials. An overview of mobile eye tracking studies in real-world, outdoor environments with a strong relation to landscape architecture is given in Nollen [5].

> 'Similar to most studies in the field of empirical aesthetics, the current study only recruited (psychology) students whose intrinsic motivation to see the artworks in uncertain. This approach guarantees homogeneous samples […] and facilities the control of level of art expertise. Nevertheless, further studies should be conducted with spontaneous art museum visitors to raise the level of ecological viability and enlarge our knowledge about art experience in the museum. [12]'

This quotation is exemplarily for a growing demand for out-of-the-lab studies and shows that the focus in future studies should be more on the ecological validity. This approach provides a guideline for mobile eye tracking research in landscape architecture as presented in the following sections.

4.1. Exploratory tests

The master thesis 'Mobile eye tracking in Landscape Architecture - Empirical testing of its capability as a new data collection method' was embedded in the long-term establishment process of mobile eye tracking in landscape architecture and the implementation of the ETC. la. All tests were conducted with ETG version 2.0 and were exploratory tests to test the glasses' applicability and limitations concerning sunlight, darkness or moving artefacts as well as basic information for designing future research designs including timelines for data collection and the very time intense analysis of gaze videos. The following subsections present two tests examining inner-city, fear-of-crime situations at night and the awareness of different service levels on pruned *Prunus laurocerasus* [5].

The following insights have not been deepened since the presentation of the master thesis and have never been presented before. Thus, this is a possibility to present and to discuss those approaches for the first time regarding mobile eye tracking as a purposeful method for developing planning guidelines for these topics.

4.1.1. Fear-of-crime causing elements at night

The objective of the experiment was to analyse the behaviour of female pedestrians in a street in the old town of Osnabrück (D) and to better understand the inner-city fear-of-crime causing situations at night using the mobile eye tracking as a data collector. The borders between subjective insecurity and fear vary broadly. This trial was an exploratory study aiming to check if there are indications for a possibility to learn about those phenomena.

(In-)Security is based on social structures, which are clustered by space, sex and power [13], whereby the material environment influences the fear of crime, for example, the brightness, structure and arrangement of objects can sometimes create a feeling of insecurity which can sometimes hardly be empathised with by men [14]. Other aspects to describe a situation are atmosphere and perception, which are closely related to personal moods and can change instantly at dusk and at night [15].

As far as is known, Guedes et al. [16] are the only ones following similar ideas to the authors but based on remote eye tracking with the presentation of stimuli on monitors. 'Fear of crime has been defined as a negative reaction to crime or symbols associated with it […]. Fear of crime (as the crime itself) has an unequal spatial and temporal distribution […]. The hot spots of crime and hot spots of fear of crime do not always overlap […]. Several authors point out the incivilities - […] such as graffiti, litter and vandalism - as having a negative impact on fear of crime […]. Blocked viewpoints where potential offenders can hide and/or areas with blocked escape are associated with fear of crime […]. Also, the lack of lighting is one of the greatest cue associated with increased fear ([16], p. 42)'.

Regarding the study area, litter, obvious vandalism such as peeled off bark or graffiti, corners, parked cars, entrances (to houses and gardens), shrubs and trees were determined to be eight potentially threatening objects/situations out of a total of 24 areas of interest (AOIs). Those eight are marked with a black dot (**Figure 8**). Recruiting participants was critical; only women were asked to take part and potential subjects were only recruited at the starting point. It was important not to recruit subjects elsewhere. They should be part of the scenery to increase the ecological validity of this study. Recruitment and conduct of trials took part during seven nights with good weather between 10:30 pm and 0:30 am. Recruitment proved difficult and led to only five participating subjects (N = 5) with sufficient local knowledge to find their way to the destination without the help of maps. All trials were conducted in addition to an RTA based on the recorded gaze video to better understand the relationship between gaze direction and emotion. In reference to Guedes et al. [16], the chosen route was no crime hotspot, neither in the crime statistics nor in the cognitive maps of the subjects.

Figures 5–7 present screenshots with heat map visualisations of approximately 1 s duration. They illustrate how the subject's gaze jumped from one object to another. Most interesting

Figure 5. Fixations on dark shrubs. BeGaze (2015).

Figure 6. Fixations on potential entrance. BeGaze (2015).

Figure 7. Revisit on garden door. BeGaze (2015).

are long fixations (dark red) or revisits, when a subject looked back at an AOI after exploring another. Revisits are crucial details in gaze videos and are a good way to identify salient situations because looking back after passing the garden gate shows the interest towards an object, and it is possible to interpret how the subject feels: doubt, fear, insecurity, and so on. By defining AOIs and creating a reference image, it is possible to code the recorded fixations and to get numeric results for proportions of looks at each AOI based on chosen parameters such as fixation duration (total or average), number of revisits or individual key indicators.

By watching the gaze videos (recorded with the ETG), it is possible to analyse and interpret relevant fixations on objects or situations. Instances of fixations on situations can be brief fixations on objects with the head turned to the left while turning right at a junction. This leads to the insight that, besides a conventional analysis based on reference images with manifested AOIs, 'Emotional Referencing' (ER) could be an alternative way to gain results. Fixations could easily be referenced to the AOIs as a 'surprising situation', 'threatening situation', 'neutral situation' or 'possibility for social interaction' leading to similar results in comparison between different researchers.

Answering the research question whether fear-of-crime causing elements can be revealed by mobile eye tracking, different procedures have been trialled. The abovementioned ER did not lead to a result because it lacks accuracy and has no link between time and space. However, it does help in understanding the emotional states of the subjects. Even focus maps as a tool to qualitatively analyse AOIs did not lead to a conclusion. Furthermore, standard parameters such as revisits and total or average fixation duration were analysed but were not useful either. Only by calculating the AOI-specific key indicator of total fixation duration divided by quantity of revisits (**Figure 8**), results can be obtained.

Knowing that every revisit means a further glance at an AOI with one or more fixations, it is remarkable that the highest value is on shrubs with 554 ms per glance. This is followed by the art object (524 ms), trees (499 ms), entrances (440 ms) and cars (430 ms). These encompass four of the determined potentially threatening objects. Considering incivilities and corners are hardly looked at, one can assume that the evaluated key indicator is able to identify fear-of-crime causing objects. The reason why the art installation has such a high value might be because of its
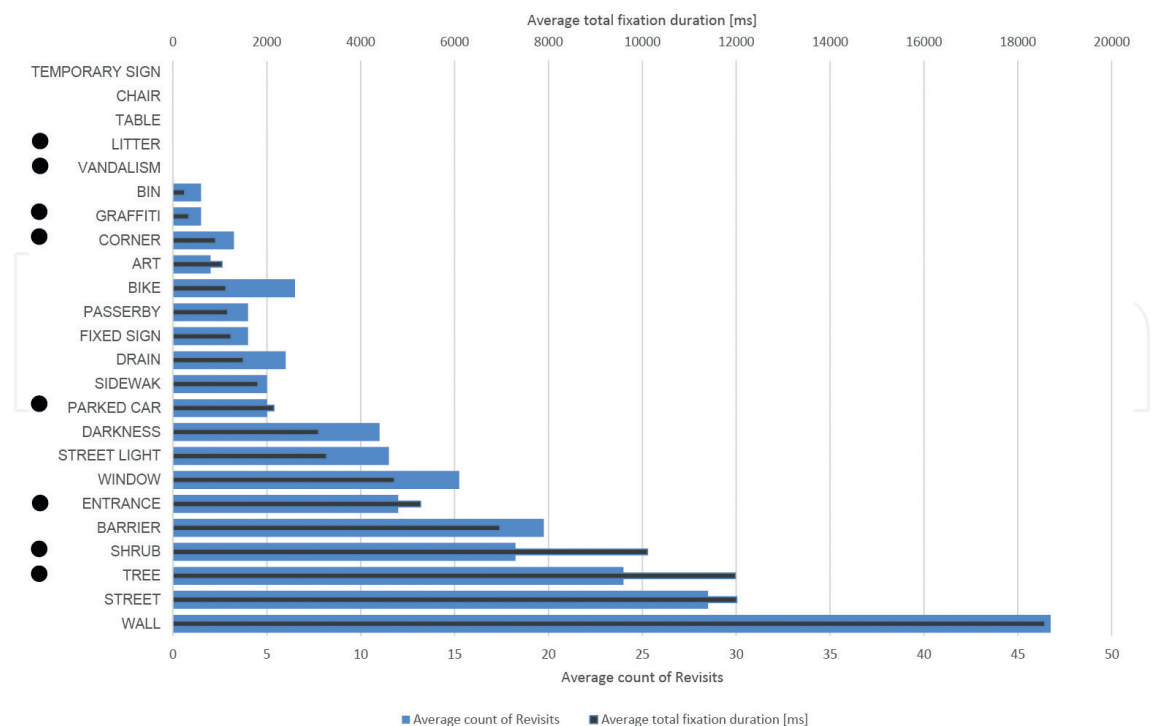

Figure 8. Key indicator for fear-of-crime causing elements. ETC.la (2015).

shape. A 3-m high figure is a potential hiding place, which was not considered to be such when defining the marked threatening objects.

It was soon recognised that investigating qualitative details such as key indicators does not provide the necessary general understanding of human interactions in open spaces. Although research questions were answered by this, it is still very important for the entire research project to qualitatively learn from the gaze videos and to comprehend how different subjects behave in order to synthetise insights and findings.

4.1.2. Maintaining public green spaces based on the users' awareness

This test study sought to investigate the users' awareness of different quality levels of pruned *Prunus laurocerasus* (Prunus l.) in one of the most important entrance areas to the campus of the Faculty of Agricultural Sciences and Landscape Architecture at Osnabrück University of Applied Sciences. This campus is called the green campus due to the study programmes on offer and its appearance as a grand park. The main structures on the chosen square are a fountain and six circular plantings of Prunus l. of approximately 6 m in diameter, each of them with a tree with pinnate leaves providing a smooth shadow. Three of those Prunus l. circles have not been pruned for a period of time and have grown up to 1.60 m, whereas the other three are nicely cut to a height of 80 cm (**Figure 9**). This square was chosen because students tend to meet there before entering the campus and a common behaviour, waiting there for somebody, can be observed. This is of importance for the trial.

The subjects were students from the campus from 11 different study programs, different sexes and ages with an average age of 25.3 years. Vision was corrected to nearly normal by adjusting correction lenses on the ETG. All trials were conducted in addition to an RTA based on the previously recorded gaze video to better understand relations between seeing and recognising. All subjects (N = 15) were spontaneously recruited in 2 days with a recruiting rate of approximately 60%. Subjects were asked to proceed alone to this well-known square as a phase of familiarisation with the ETG. They were told that the researcher would approach

Figure 9. Pruned and unpruned *Prunus laurocerasus*. ETC.la (2015).

them there to give them the task for the trial. After 4–5 min, when the subject was obviously bored, the trial was stopped.

The phase of boredom was important for the trials because it was an incidental investigation of what subjects do when bored and whether mental states shifting from boredom to searching could objectively be defined by different researchers.

Answering the main research question if there is a difference in the awareness of users towards different quality levels of pruned Prunus l., the results seemed to contradict what only becomes clearer when quantitative and qualitative results are combined. The quantitative results indicate a preference for pruned Prunus l. represented by a higher fixation rate (4.65% compared to 3.73% on unpruned Prunus l.), a higher average fixation duration (222 ms compared to 122 ms on unpruned Prunus l.), a greater number of revisits (8.4 compared to 6.2 on unpruned Prunus l.) and a total fixation duration over all subjects of 57.594 ms which is 2.25 times longer than on unpruned Prunus l. Only the sequence shows a different image: over all subjects, the unpruned Prunus l. was the first AOI to be looked at followed by the pavement, tree trunks, tree crowns and pruned Prunus l., on rank 5, followed by the rest of the defined 26 AOIs.

The result of the RTA is that only five subjects (33%) mentioned the Prunus l. but without naming differences between pruned and unpruned ones.

Against the background of the research question, it is remarkable that pruned Prunus l. were regarded more frequently and longer, but this has to be questioned by the qualitative results of the RTA as well as general trial observations such as the spatial distribution of the different Prunus l. Half of the Prunus circles had been pruned randomly by the gardeners, but the trial observation shows that those in the direction where the subject came from were unpruned. On the other hand, pruned Prunus l. were close to the sunny area, where subjects stopped to wait. Additionally, nobody named the different quality levels of maintenance even though the subjects talked about the quality of other materials and overall design quality.

The results can also be interpreted in two other ways. On the one hand, subjects unconsciously chose an area with more pruned Prunus l. to wait for somebody or, on the other hand, they displayed a deepened consideration of the spatial distribution in relation to their maintenance quality. So, one can assume that pruned Prunus l. were coincidentally closer to the main waiting position and that the unpruned Prunus l. in the background did not lead to losses in the overall quality awareness. This implies the possibility to define quality awareness ranges to govern maintenance and care of public green spaces. This in turn means less intense maintenance, while holding the same quality awareness level, or to invest the same amount of human resources while increasing the quality awareness level.

4.2. Feasibility study 'Point de Vue'

The research project 'Point de Vue' sought to investigate the effects of gaze guidance and usage behaviour in promenade gardens from different eras and styles by utilising mobile eye tracking (ETG 2w). This represents a study of the feasibility of the implementation process of mobile eye tracking as a new method in landscape architecture. Furthermore, it was of interest to examine the impact of 'Points de Vue' on interactions in and with the stimulus and if
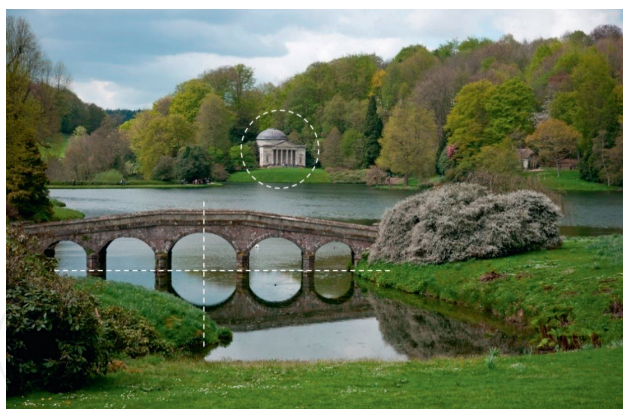
Figure 10. 'Point de Vue': world-famous scenery in Stourhead landscape garden. ETC.la (2016).

mobile eye tracking generally is an appropriate method for landscape architecture. During three research trips of 4–6 days each, it was possible to recruit approximately 90 subjects and to record gaze videos of their experience and thereby carry out suitably grand-scaled research. The trials were conducted in the baroque garden Grosser Garten in Hannover (D) which is a part of Herrenhausen Gardens and the masterpiece Stourhead landscape garden in Wiltshire (GB), which is run by the National Trust (**Figure 10**). Despite all the differences in garden types, both parks combine historical, local and superregional importance and they claim to offer the paying visitors an excellent park experience. Subjects were recruited in situ in the reception building (Grosser Garten) or while passing the outdoor-lab, as presented earlier (**Figure 3**). Recruitment rates were better, if done in the outdoor-lab instead of in the reception building [7]. The CSX method (see Section 3) was applied and stimuli were presented in unmodified conditions. To observe the most natural behaviour, no task was given to the subjects or to their companions.

4.2.1. Learning from experimental procedures

When developing the research designs, there were worries about recording too much gaze video material because gardens are very big and strollers can spend several hours in the gardens. This is why a small timer was given to the subjects on the first research trip to Grosser Garten. After 30 min, it rang and they were asked to proceed to the Great Fountain. However, even this procedure influenced the behaviour too much and came close to ruining these trials. Therefore, it was decided to remove these limitations for the subsequent research trips to Stourhead, which enabled the recording of natural interactions. A big advantage of the CSX is that, in comparison to the (R)TA, the subject does not have to verbalise something and the video does not have to be reviewed afterwards. That saves time for both the subject and the researcher. Instead, it increases ecological validity, and during the analysis process, the stimuli for verbalising something can be speculated upon.

Considering **Figure 11a** and **b**, it becomes obvious that subjects in Grosser Garten had a greater variability in route selection and became confused by repeating geometrical structures. As a result, they tended to turn around quite often, which in turn made the analyses very difficult. Subjects used different paths to get to the final point leading to an enormous
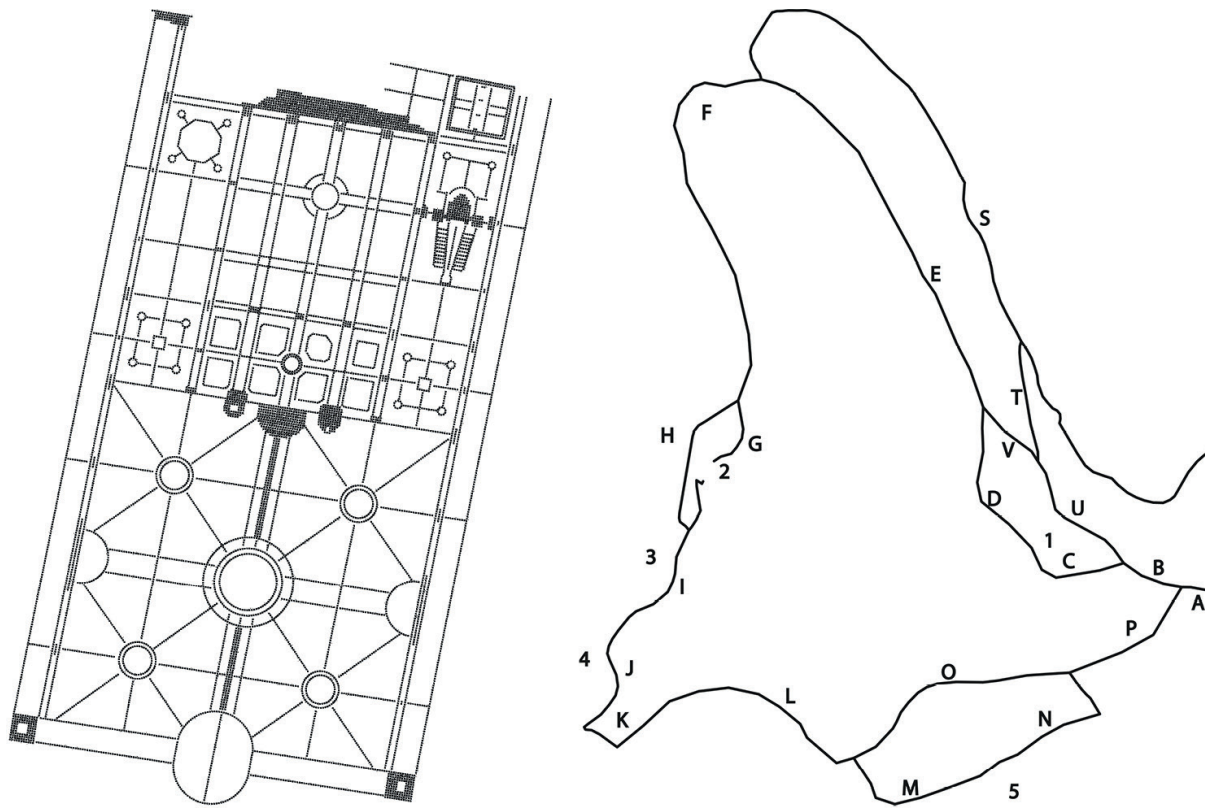
Figure 11. Comparing path networks in (a) Grosser Garten and (b) Stourhead (both unscaled). ETC.la (2017).

reduction of subjects in certain areas. These two constraints reduced the quality of the path-related interaction protocol as well as the possibility of creating representative gaze interaction images like heat maps or scan path diagrams. The problem of creating time consuming and, coincidently, poor PrIPs for Grosser Garten could have been solved if GPS-trackers had been added. Despite that, it was a trial with meaningful insights, and in this phase of the study, it was more important to develop the CSX and to learn about general coherences between potential subjects and the park as a real-world environment stimulus. Future studies will be conducted in combination with GPS-tracking.

4.2.2. Key results of 'Point de Vue'

Against the background of 'Point de Vue' being a feasibility study with uncontrollable real-world environments as stimuli, it can be seen as a self-learning, knowledge process. The cluster of evaluated results and gained insights can be summed up as the overall acquired knowledge.

One of the main results is that mobile eye tracking is a proper application for research in landscape architecture, unfolding its power through various possibilities for analysing the object, the subject and interactions between both. This is why the focus in the analyses switched from quantitative to qualitative. The fixation analysis is now seen as a way to deepen the qualitative findings without a main outcome. This leads to a definition of the research area as qualitative interaction analysis.

CSX has to be mentioned once again with reference to Section 3. It is of particular importance because it is the basis for further analyses and the only possibility to be an 'invisible companion' for the entire length of the trial, which can be over 2 h long. Only because of this fact, it is possible to run mobile eye tracking trials in such extensive gardens and landscapes.

'Point de Vue' also showed that the ETG are comfortable enough to wear for a couple of hours and that the developed analysis methods, VMM and PrIP, are able to deal with the enormous volumes of recorded data.

4.2.2.1. Path-related interaction protocol

The PrIP is a map-based evaluation method and result chart developed during the 'Point de Vue' study. It represents different kinds of interactions during the study. In a first step, only the chosen routes were transferred to the PrIP, which showed that track and path networks in Stourhead were not always identical. Later, additional information was evaluated and displayed: the frequency on path segments, average walking speeds or stops (resting times and places), including gaze direction and objects of special interest (**Figure 12**).

Figure 12 is presented as an example for a PrIP and visualises stops and remarkable viewpoints together with the predominant gaze direction for a sample of 10 subjects (n = 10). Stops are marked with the total resting time [sec] if two or more subjects have stopped at the same place. Beyond the quantitative stopping time, one can see a blue square indicating the stopping time through varying sizes. Stops can have multiple reasons and only if people stopped to enjoy the view on a focal point or the scenery, this is marked with a blue triangle. Other
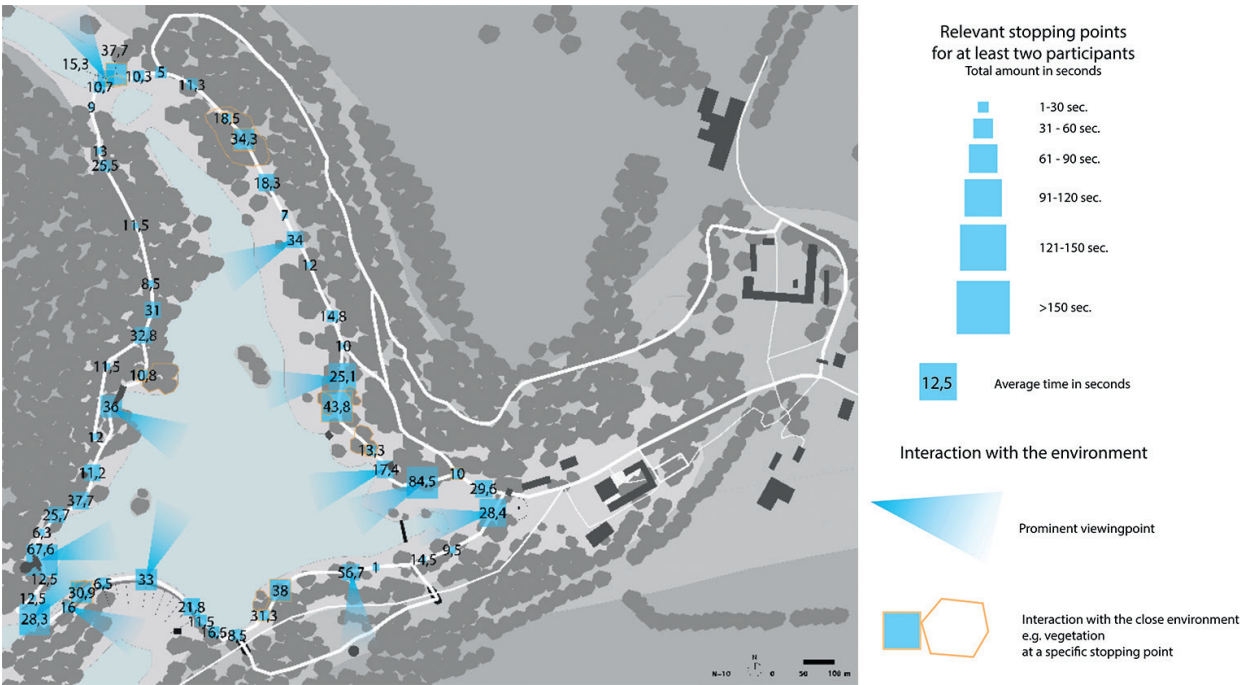

Figure 12. PrIP with stops and gaze directions in Stourhead. ETC.la (2017).

main purposes for stopping were the interaction with vegetation such as big trees or flowering bushes. If remarkable, these objects are marked with an orange outline.

This map enables a differentiation between seasonal focal points or objects, which are not recognised in a way they should be, which leads to the analysis of historical and current viewpoints.

4.2.2.2. Verification of viewpoints

Many viewpoints have been planned as such and are still manifested in historic parks. They are usually on, or at least close to, buildings or constructions. Some examples are the balcony at Herrenhausen castle or the nearby platform on the Great Cascade from where a beautiful view over the Great Parterre of Grosser Garten is provided. Stourhead has multiple viewpoints all around the lake and all of them are likewise associated with buildings or constructions.

Nijhuis presents these viewpoints against the historical background (**Figure 13**, left) ([3], p. 217). Current interaction analyses indicate minor, but relevant, changes. Comparing the maps in **Figure 13** (right), most of the traditional viewpoints were confirmed, but the one on the bridge close to the Pantheon was defined as a new viewpoint. This is based on measured stopping times, explicit verbalisations and locally occurring changes in interactions. In addition to the numbered viewpoints, the authors also defined landscape windows (L), which are lookouts of minor relevance, based on gaze video and interaction analyses. They are, for example, short impressions or picturesque views one gets 'along the way'. Even, or especially, those views have to be recognised as important for the subconsciously gained, overall impression and thereby have to be maintained and developed by the gardening team responsible for the maintenance.
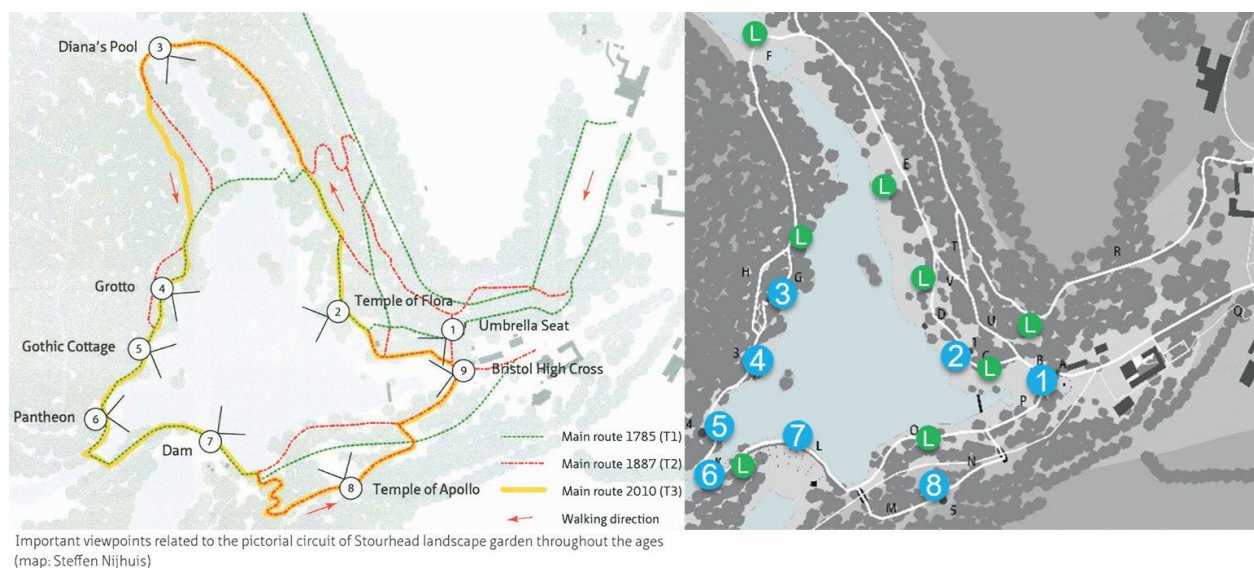

Important viewpoints related to the pictorial circuit of Stourhead landscape garden throughout the ages
(map: Steffen Nijhuis)

Figure 13. Comparison between historical and current viewpoints in Stourhead. Left: Nijhuis (2015), right: ETC.la (2017).

Another important piece of information is that viewpoint 1 (Umbrella Seat) [3] is marked as a landscape window in the above-mentioned figure. This was due to the fact that while trials in Stourhead were conducted, there was no building or construction as in former times and shrubs began to grow high. But this situation was restored in summer 2017 by installing an enormous curved bench in combination with the associated gardening works. So, from then on, it has been a viewpoint again.

4.2.2.3. Gaze metrics

Gaze metrics can be visualised overlaid on reference images to represent inter alia fixation durations, sequences or gridded distributions of, for example, revisits. **Figure 14** compares the heat map with the average number of revisits displayed as a Gridded AOI. There is only one intersection of the respective hotspots, which is in the centre next to the Pantheon. This area provides the most dynamic composition: starting with the upper edge of the bridge, going up to the reflecting water surface, the architecturally curved dam, the natural shoreline beyond the Pantheon, an early-autumn colouring shrub and the intensively viewed left edge of the Pantheon. All this is arranged in the centre of this prominent viewpoint and is visible with one glance and thereby easy to perceive.

This seems to be a clear reason for the concentration of visual attention in this region and why this is the most prominent viewpoint and typical postcard image. But regarding the isovist on the plane of the water level, it is clear that the whole shoreline cannot be explored in the region and thus also the extended lake which lies behind the visible scenery [17]. This means a higher cognitive workload for the visitor which supports the general tension as described earlier. This scenery is highly complex and many more investigations will be necessary to disclose all the secrets of this beautiful scenery.

4.2.2.4. Positive effects on visitors

In addition to the mobile eye tracking trials and the applied CSX, the authors conducted guideline-based interviews and asked ordinal and interval-scaled questions [18]. As briefly described in Junker and Nollen [7], one of these questions asked whether the garden was interesting for children. Comparing the interestingness of Grosser Garten for children to the
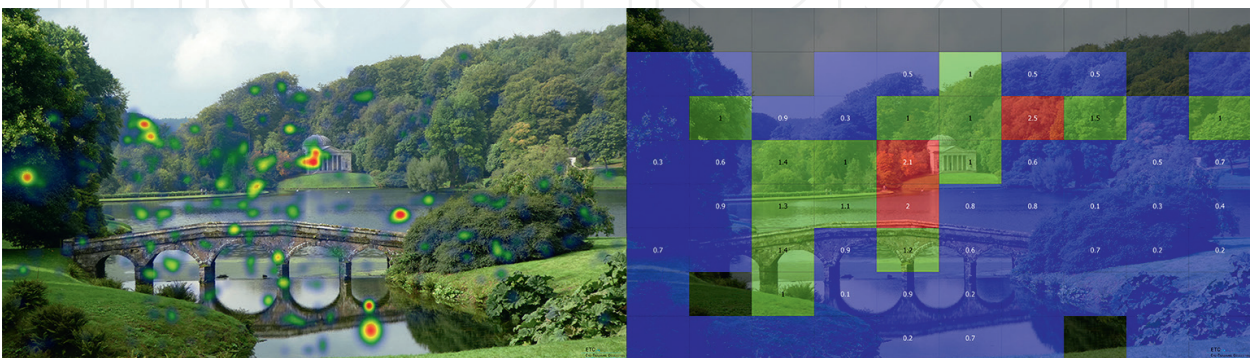

Figure 14. Heat map (left) and gridded AOI (right) overlaid on viewpoint 1 (Bristol Cross) in Stourhead. ETC.la (2017).

adult's assumption of how interesting the garden was for children, the difference in weighted mean shows a + 2.23 points greater mean (scaled from 1 to 10) for the children group (≤ 18 years) and families accompanied by children (7.23, n = 15) in contrast to adults walking without children (5.04, n = 26) [7]. This result goes in line with analysed gaze videos from juvenile subjects and the general observations, which show that children interact more actively by means of playing and running around with peers and adults or multi-sensorial, exploring the stimulus; but always with great respect for the age and wealth of detail. Strolling in the garden seems to be a time spent together with the family and away from electronic devices. That is why children are not bored as adults interact with them.

Another aspect was to have a look at mood changes by using four opposite pairs of words such as tired/rested, withdrawn/talkative, nervous/calm and inattentive/focussed. Subjects marked their current mood on the sheet directly after recruitment (before setup and further explanations) and then directly after arriving back at the endpoint (before taking off the ETG and doing the interviews). The overall mood changes—potentially caused by spending time in a park— are predominantly positive with the mood score (scale from 1 to 7) increased by +7.63% (Grosser Garten: +8.28%, n = 39; Stourhead: +6.31%, n = 19) [7].

5. Conclusion and prospects

Within the framework of several master theses and the feasibility study 'Point de Vue', the method of mobile eye tracking was successfully implemented in landscape architecture. 'Point de Vue' was a basic research gaining impressive qualitative and first quantitative results, which are fundamental to follow-up projects. The guiding, resulting method is the described common shared experience (CSX), as an experimental method which, in line with the effect of the 'invisible companion', proves the unobtrusive functionality of mobile eye tracking in real-world, open-space environments. This chapter concludes that mobile eye tracking will be a relevant tool in many different approaches for making open spaces better and for, consequently, increasing the quality of life.

More efforts must be invested in the further development of map-based path-related interaction protocols (PrIP). These complex illustrations are based on multi-methodical data collections and analyses, enabling better knowledge transfer. Furthermore, the method combinations (**Figure 4**) to record even more detailed interaction and analyses of body responses offer great potential. GPS is an out-of-the-box technology but requires method development in terms of GIS-based PrIPs and also mobile EEG-measurement, which will be a basic research in itself.

A next step will be to enhance the developed experimental and evaluation methods and to apply them in various subsectors of landscape architecture. One idea amongst many is to define a pioneering method to analyse and to optimise intersections of the (im)material provisions of an open space and the user's expectations thereof along with documentation of the behaviour. The basis for this will be developed and tested approaches such as the CSX. It will be a holistic approach within the qualitative interaction analysis with strong relations to usability, user experience and human machine interaction, never losing sight of the human.

Finally, it is necessary to say that mobile eye tracking will hardly be used as a problem-solving method, but instead for generating outstanding, specific knowledge such as analysing user's demands, questioning the adequacy of (realised) planning measures, managing green spaces including public housing, the subjective sense of security, coherences between historical garden arts and contemporary aesthetics and many more.

Acknowledgements

Nomenclature/list of abbreviations

Common Shared Experience (CSX)	An experimental method for mobile eye tracking trials developed by the ETC.la. The CSX has similarities to the think aloud protocol.
Eye Tracking Collective.landscape architecture (ETC.la)	Eye tracking laboratory specialised on analysing human interactions in real-world environments under non-laboratory outdoor conditions.
Eye Tracking Glasses (ETG)	Mobile eye tracking device by SensoMotoric Instruments. Versions used: 2.0 and 2w both with smartphone recording unit
Gaze video	Recorded by the HD scene camera of the ETG with overlaid fixations, represented as circles or crosshairs.

Isovist	An isovist is the set of all points visible from a given point in space and with respect to the environment [17]
Path-related Interaction Protocol (PrIP)	Map-based evaluation method and result graphic developed by the ETC.la. It represents different kinds of interactions during the stroll such as average walking speed or resting times.
(Retrospective) Thinking Aloud [(R)TA]	Protocol of the subject's verbalisations recorded during (or after) the trial. It is a complementary method, which helps understanding the behaviour of the subject.
Stimulus	The stimulus is the presented research object, meaning the garden/park, including the whole environment with its entirety of objects. By interacting with or within the stimulus, the subject is able to influence it and thereby become a part of it.
Verbal Mood Map (VMM)	Map-based evaluation method developed by the ETC.la. It visualises the agglomerated verbalised spontaneous reactions to create a link between the viewpoint and the perceived stimulus (focal point).

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