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1 INTRODUCTION

Landscapes are important in our every-day activities and their condition affects our quality of life. Consequently, people are concerned when these landscapes are subject to change (Scott & Moore-Colyer, 2005). However, landscape management and development policies are often very top-down driven. Strategies are formulated by experts while the opinion of the public is insufficiently considered (Harrison & Burgess, 2000; Luz, 2000; Pinto-Correia et al., 2006). As a reaction, an increasing number of researchers express the need to incorporate public perception approaches in landscape management processes, as it is the public who eventually will experience the new developments (De Groot, 2006; Nassauer, 1997; Seddon, 1986; Vouligny et al., 2009). This participatory methodology is also strongly promoted by the European Landscape Convention (Council of Europe, 2000) and the Aarhus Convention (UNECE, 1998).

Landscape change essentially affects the visual aspect of the landscape and policy makers usually seek to limit this impact (Dakin, 2003; Gobster et al., 2007). A widely used method to evaluate landscape management and development consists of using landscape photographs and simulations. This technique also seems particularly effective in informing a lay public about landscape changes (Bishop & Rohrmann, 2003; Ryan, 2006; Tress & Tress, 2002) and is therefore increasingly gaining importance in landscape management and design (Al-Kodmany, 1999; Lange, 2005). Landscape visualisations have, for example, been used for assessing environmental management planning (e.g. Sheppard & Meitner, 2005), for evaluating the visual impact of wind turbines (e.g. Del Carmen Torres Sibille et al., 2009; De

Vries et al., 2012; Lothian, 2008; Thayer & Freeman, 1987; Tsoutsos et al., 2009) and for assessing landscape management in general (e.g. Dandy & Van Der Wal, 2011). However, although visualizations could facilitate the dialogue between policymakers, planners and designers (experts) and the general public (non-experts) (Lange, 2005), often both groups seem to have opposed views when it comes to evaluating landscape changes visually (Bell, 2001; Godschalk & Paterson, 1999). These differences may be related to the way people literally perceive their environment. Research has demonstrated that the same landscape may indeed elicit different perceptions by different people (Brabyn, 1996; Conrad et al., 2009). This could be a result of the fact that not everyone observes a landscape in the same way and thus that different persons do not necessarily see the same landscape. As a result, different groups of observers may also perceive different features as being the key aspect of a specific landscape. In particular, this could be an issue in visual landscape assessment studies based on landscape photographs in which different groups of observers are consulted. If those groups indeed observe landscapes differently, the probability of having diverging opinions increases as different people might literally not see the same landscape. However, research on how landscape visualizations are perceived is still underexplored (Lange, 2005), while this could perhaps explain the discord between landscape experts and lay people when it comes to visual landscape assessments. In this context, Sevenant (2010) reports that perception is selective and intelligent, which is illustrated by the statement ‘you see what you know or recognize’. Differences in people’s intellectual and/or social background, related to acquired knowledge, experience, culture, ethnicity et cetera, will influence what is known, what will be recognized and thus what will be seen. In-depth analysis of how persons with different backgrounds observe landscape(s) (photographs) could be very useful in better understanding how disagreements between landscape experts and lay people concerning visual landscape aspects arise. This information could also help to more easily resolve such issues.

In this study, we analyse if landscape experts, who acquired knowledge and (professional) expertise in landscape related topics, indeed observe landscapes differently from the general public and how this is reflected. To this end, we conducted an eye tracking experiment, in which landscape experts and laymen were asked to observe a number of landscape photographs. During the experiment, the observer's point of regard, as well as the direction of his/her eye movements (or saccades) were continuously recorded. These data subsequently allow a complete reconstruction and analysis of the gaze pattern made while observing the landscape photographs. The first research objective is related to the hypothesis that the global viewing pattern differs between landscape experts and laymen. It is expected that experts visually explore a landscape differently from lay people because of their expertise in landscape related issues. This is investigated in this paper. The second research objective is to determine on which elements in a landscape experts and lay people fix their attention and if significant differences between both groups exist. To explore this, we perform statistical analyses, as well as a qualitative examination of the eye tracking data. Comparing image perception of experts and novices has been applied in many eye tracking studies in several domains of interest. Examples are given by Landsdale et al. (2010) (experienced versus untrained users of aerial photographs), Hermans & Laarni (2003) (experienced versus novice map users), Mourant & Rockwell (1972), Underwood (2007) and Konstantopoulos (2009) (advanced versus novice drivers), Krupinski (1996) and Litchfield et al. (2008) (experienced versus inexperienced radiologists), Mann et al. (2007) and Cañal-Bruland et al. (2011) (professional sportsmen versus novices), Reingold et al. (2001) (professional chess players versus novices), Nodine et al. (1993) and Vogt & Magnussen (2007) (artists versus artistically untrained participants) etc. All of these studies found significant differences between the observation patterns of experts and novices. However, in landscape research, eye tracking is a relatively new technology. Except for the studies of De Lucio et al. (1996) (analysis of the exploration strategies of men and women in natural landscapes), Berto et al. (2008) (analysis of the types of attention when viewing landscape photographs), Tveit et al. (2010) (investigation of which aspects of a landscape are important when assessing its stewardship), Nordh et al. (2012) (analysis of eye movement patterns when rating restoration likelihood while viewing landscape photographs) and Dupont et al. (2014) (analysis of how photographs properties and landscape characteristics affect the viewing pattern) this technology has been little used in this field so far.

2 METHODS

2.1 Subjects

Two groups of 21 subjects each participated in the eye tracking experiment. The expertise groups were formed based on the educational and/or professional background of the subjects, by analogy with previous studies concerned with expert-novice differences (e.g. Dyer et al., 2006; Hermans & Laarni, 2003; Konstantopoulos, 2009; North et al., 2009; Vogt & Magnussen, 2007 etc.). Participants who are actively working or studying in landscape related fields were assigned to the ‘landscape expert’ group. Subjects without such educational or professional background were assigned to the ‘laymen’-group. In practice, the expert group consisted of landscape researchers, landscape ecologists, landscape architects and planners and students who were finishing a Master in Geography with a specialisation in Landscape Research. For the laymen group subjects who were unfamiliar with landscape related topics were chosen. In total, 42 persons (18 males and 24 females), aged between 22 and 65 and naive with respect to the purpose of the study, voluntary participated in the experiment. All subjects had normal or corrected-to-normal vision.

2.2 Photograph stimuli

In total, 74 colour photographs, representing a variety of rural and more urbanised landscapes in Belgium and northern France were used as stimuli. A range of different most common landscape types was chosen in order to be able to generalise the results of the study (for Belgium and the north of France) as much as possible. Figure 1 gives an idea of the landscapes included in the study. All photographs were taken with a constant focal length of 50mm using a tripod to assure a constant shot height (1.70m). All images subtended 31° (width) x 21° (height) of visual angle.

Landscape photographs were used as stimuli for several reasons. First, we used a non-portable eye tracker, which excluded performing the experiment in situ. Moreover, taking the participants to the physical environment itself has many limitations, in particular in controlling the settings of the experiment. Second, numerous studies have demonstrated photographs to be valid surrogates for real landscapes (Coeterier, 1983; Palmer & Hoffman, 2001; Shafer & Richards, 1974; Shuttleworth, 1980; Zube et al., 1987). We thus assume that eye-tracking results based on photographs are similar to tracking results obtained in the real world.

Fig. 1. Examples of the landscape photographs used in the eye tracking experiment.

2.3 Eye tracking apparatus

The eye tracking data were measured by a non-portable RED-eye tracking system, developed by SMI (Senso Motoric Instruments, Germany). Eye tracking technology is based upon low power infrared light, which is sent into and reflected by the eyes of the observer. From this reflected signal the precise x,y-coordinates of the observer's point-of-regard is calculated (Jacob & Karn, 2003; Poole & Ball, 2005). As a result, this technology allows a continuous registration of the observer's fixation point while observing images displayed on a 22-inch colour monitor at a screen resolution of 1280 x 1025 pixels. The RED-system uses a measurement rate of 120 Hz, meaning that the gaze direction is recorded 120 times per second. Consequently, the entire gaze pattern, consisting of fixations and interconnecting eye movements or saccades can be reconstructed (Poole & Ball, 2005). Furthermore, it is also possible to detect the centres of attention in the images, which are the areas in the image that drew most attention. Unlike some other eye tracking systems, the RED-system records both eyes. This offers the advantage of having back-up data of the second eye when for some reason the data of the right eye (usually used) turns out to be unusable. Furthermore, no chin rest is used. The observer is not restricted in his/her movements, which contributes to the participant's comfort. However, subjects were asked not to move too brusquely, but make themselves comfortable in a static pose to avoid imprecise or erroneous measurements. The seating and monitor were adjusted in a way that the eyes were approximately in the middle of the screen, creating optimal tracking conditions for both eyes.

2.4 Procedure

The experiment was run in individual sessions of approximately 20 minutes and took place during six days in May 2012 in the Eye Tracking Lab of the Department of Geography at the University of Ghent. At the beginning of the experiment, participants were asked to complete a questionnaire concerning personal information, including background information like education. The test consisted of free viewing the 74 landscape photographs, each displayed for 10 seconds. Free viewing means that the participants were not given an active task to look at or search for particular features, so that real life outdoor landscape observation was simulated. Instead, subjects were instructed to observe the landscape photographs attentively. The display order of the photographs was randomized to avoid the emergence of order effects in the data. During the experiment, the participants were seated at a viewing distance of 60 to 80 cm. Before each test, a calibration was executed, using a 9-dot calibration procedure, allowing the system to match the pupil-centre/corneal reflection relationship to the specific x,ycoordinate of the fixed dot. After nine dots, an accurate calibration over the whole size of the screen is achieved (Goldberg & Wichansky, 2003). When subjects started deviating from these initial calibration conditions (see drift correction explained below) because of unintentional brusque movements or eye problems, the calibration procedure was repeated. In order to avoid fatigue effects, the participants were given the opportunity to take a break at any time during the experiment. This is necessary because it has been reported that observing images on a computer screen frequently causes eye fatigue (Blehm et al., 2005), which manifests itself by a decrease in the number of eye movements (Van Orden et al., 2000) and in their accuracy (McGregor & Stern, 1996). Each break was followed by a new calibration. Prior to each trial the subjects were instructed to fix a dot, shown in the centre of a blank screen to check for increasing measurement errors (drift correction) and to provide consistency on the initial conditions of the observation path of each photograph. For the analysis, the first fixation on each photograph was excluded as this was always located in the centre of the image and would thus bias the results. During the trials the system constantly recorded the fixations and eye movements (saccades) of the subject. A fixation can be defined as "the moment when the eyes are relatively stationary, taking in or encoding information" (Poole & Ball, 2005). Consequently, a fixation is characterized by a minimum duration, typically between 100 and 200 milliseconds (Jacob & Karn, 2003). Inhoff & Radach (1998) advise to set the lower threshold for defining a fixation on at least 100 milliseconds. Therefore, in our study a stationary eye position was considered as a fixation when lasting for at least 100 milliseconds. The fixation related metrics, which are relevant in studying the gaze pattern and thus relevant in our research, are the number of fixations and their duration (in milliseconds). Saccades are the eye movements that interconnect two fixations and orient the eyes to the next viewing position (Poole & Ball, 2005). In this study, we investigated the number of saccades and their amplitude (degrees) as these metrics offer insight into the main observation pattern. In addition, the entire scan path was analysed as well because it offers the possibility to find out how the observer has examined the image. According to Holmqvist et al. (2011), a scan path is the route of oculomotor events through space within a certain timespan, which assumes that the path has a beginning and an end and thus a length.

2.5 Data analysis

2.5.1 General analysis of ETM

For the statistical analysis of the Eye Tracking Metrics (ETM), the data recorded by the eye tracker were converted into well-structured Excel-files in 'BeGaze', a software program supplied with the equipment. These files were subsequently used to perform the statistical analysis in SPSS. The main research question is whether experts observe landscapes differently from lay people. Therefore, a comparison of means between both groups of observers was carried out for the following metrics, which are indicative for the main gaze pattern: number of fixations, fixation duration, number of saccades, saccade amplitude and scan path length. As most eye tracking measures do not follow a normal distribution (Holmqvist et al., 2011), a non-parametric Mann-Whitney U-test was performed. This test, based on ranks, is used to detect whether observations in one group (experts) tend to be significantly larger or smaller than observations in another group (laymen). If the mean ranks are found to be significantly different, the observations in the two groups will significantly differ as well. Luminance maps illustrate the results of the analysis. These can be described as two-dimensional visualizations or 'maps', representing the spatial distribution of a scan path (Holmqvist et al., 2011). Luminance maps or attention maps are based on fixations and thus represent the areas that have been given attention by the observer. The scan paths, including fixations and saccades, are visualized on the original photographs as well.

2.5.2 Spatial distribution of Voronoi cells

Although the number of fixations and scan path length give a rough idea of the proportion of the image that has been inspected, these metrics do not offer certainty about the extent to which the photograph has been observed. Fixations can, for example, be clustered in one part of the image, which may lead to erroneous conclusions concerning the viewing extent, when based solely on fixation number and scan path length. As a result, an additional analysis was carried out to see to what extent experts' and laymen's fixations are spread out over the photographs. In literature this 'extent' is often referred to as 'fixation dispersion', 'distribution of gaze intensity' or 'spread of search' (Holmqvist et al., 2011). One manner to quantify this dispersion is the Voronoi cell mapping, introduced in eye tracking analysis by Over et al. (2006). This method consists of attributing each fixation one cell, which is formed by a set of points in space whose distance to the given fixation is smaller than their distance to any other fixations (Figure 2). The Voronoi cells were automatically calculated and drawn in ArcGis 9.3 using the Spatial Analyst tool after loading the fixations as point layers. When fixations are dense, the Voronoi cells will be small. Dispersed fixations will be characterized by large Voronoi cells. For the analysis, the areas of the Voronoi cells corresponding to the fixations of the experts and lay people were automatically calculated in ArcGis and compared using a Mann-Whitney U- test.

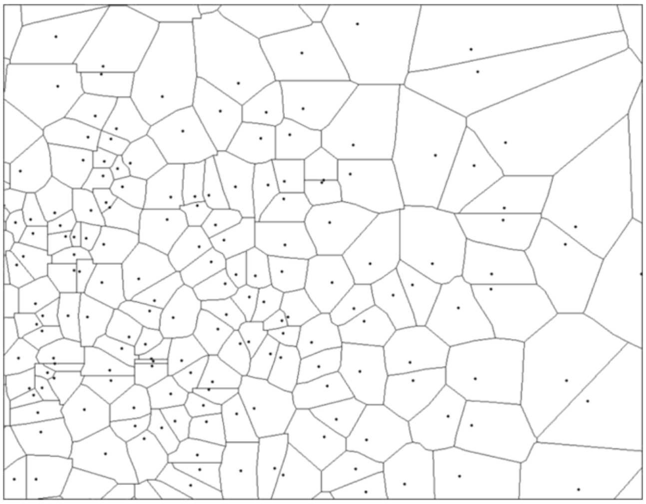

Fig. 2. Fixations (dots) with their corresponding Voronoi cells.

2.5.3 Analysis of 'interest areas'

The general analysis of the ETM and the analysis of the spatial distribution of the Voronoi cells are used to understand the main observation pattern. However, no information is obtained about which objects in a landscape attracted the observer's attention. To answer this question we performed an exploratory screening of the luminance maps, created for each observer and each photograph. Based on the knowledge obtained from this qualitative analysis the most frequently observed elements could be identified. To perform a more quantitative analysis, polygons marking these objects were drawn on the photographs in BeGaze (Figure 3) (see section 3.4 for more details about the content of the interest areas). These 'interest areas' were subsequently used to calculate a number of eye tracking metrics restricted to these areas and thus offering information about the viewing pattern concerning these specific areas. First, we calculated the number of visits per interest area for each observer. This is the number of times that a subject entered an interest area during the 10 seconds viewing time. The second interest area-metric is the time at which the first interest area of a photograph was entered.

This provides information about how fast the objects in the interest area caught the observer’s attention. Furthermore, per subject, the number of fixations in each interest area was counted in absolute terms and as a proportion (%) of the total amount of fixations one has made in the image. In addition, the fixation time in each interest area was obtained by totalizing the duration of the individual fixations made in the interest area. This metric was also expressed as the proportion (%) of the entire viewing time (10s) that was spent in the interest area. Finally, the duration of the first fixation in each interest area was included in the analysis as well. To detect any differences between the expert and laymen group, a statistical analysis (Mann-Whitney U-test) was performed on each metric.

Fig. 3. Illustration of the ‘interest areas’, which mark the buildings.

3 RESULTS

3.1 Fixations, saccades and scan path

For all ETM the Mann-Whitney U-tests indicate significant differences between landscape experts and laymen ($P < 0.05$) (Table 1).

Table 1. Results of the Mann–Whitney U-test (mean rank). Maximum values are indicated in dark grey, minimum values in light grey. Recorded mean values for each ETM are given for the experts and the non-experts. N gives the number of observations.

Eye Tracking Metric	N	Mean rank		P	Real mean values	
		Experts	Non-experts		Experts	Non-experts
Number of fixations	99,494	53,913	45,395	0.000	33	31
Fixation duration (ms)	99,494	48,993	50,536	0.000	264	273
Number of saccades	95,189	50,420	44,657	0.000	33	31
Saccade amplitude (°)	95,189	46,761	48,462	0.000	4.5	5.1
Scanpath length (px)	3,108	1,650	1,459	0.000	6,638	6,348

Experts seem to make significantly more fixations and saccades – both are inherently associated with each other – in the same amount of time compared to lay people ($P < 0.05$) (Table 1). During the 10 second trials experts were able to produce 33 fixations on average, compared to 31 fixations for the laymen. In addition, landscape experts' fixations are on average of shorter duration (264 ms) than those made by non-experts (273 ms) ($P < 0.05$) (Table 1). Furthermore, the Mann-Whitney U-test points out that the scan paths of the landscape experts are significantly longer (in fact, the on average shorter saccadic amplitude is completely drowned out by the significantly higher amount of saccades) than those made by the laymen group ($P < 0.05$) (Table 1 and Figure 4, section a and b). While an expert covers an average distance of 6,638 pixels when observing a landscape photograph for 10 seconds, a non-expert's mean distance is 6,348.

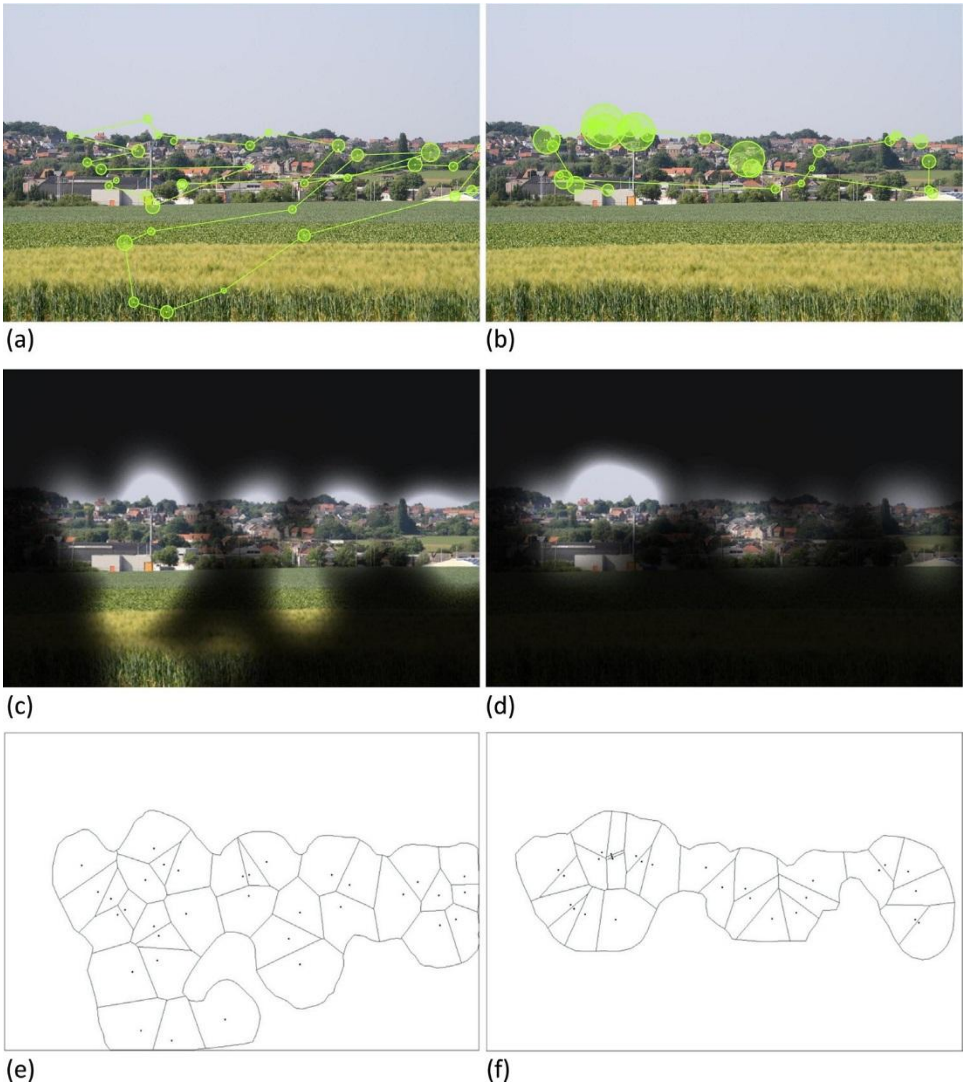

Fig. 4. Scan paths of a landscape expert (a) and a non-expert (b), their corresponding luminance maps (c) and (d) and Voronoi cells constructed around the fixations and restricted to the observed area (e) and (f). In the scan path visualizations the size of the circles increases with fixation duration. On the luminance maps, the visible parts are the areas that have been viewed by the observer; the dark parts have not been given any attention. All representations are derived from fixations (detection from 100 ms) and are based on the entire 10 s trial.

3.2 Visual span

Figure 4 (section c and d) presents luminance maps for a landscape expert and a layman, derived from the scan path representation given in (a) and (b). Although the maps suggest that the area observed by the expert is larger and more extended than the non-expert's viewed area, quantitative analyses of luminance maps are difficult. Therefore, we performed an additional analysis, using Voronoi cells constructed around each fixation and restricted to the observed area in the luminance map (Figure 4, section e and f). The results of the Mann-Whitney U-test, in which the areas of the Voronoi cells corresponding to the fixations of the landscape experts and the laymen are compared, indicates a significant difference between the two groups ($P < 0.05$) (Table 2). In particular, the expert group is characterized by larger Voronoi cells, while for laymen they are significantly smaller.

Table 2. Results of the Mann–Whitney U-test for the Voronoi cell areas. Maximum values are indicated in dark grey, minimum values in light grey. N gives the number of observations.

	N	**Mean rank**		**P**
		Experts	**Non-experts**	
Voronoi cell surface	99,494	48,968	47,875	0.000

3.3 Focus: where do people actually look at?

The luminance maps show that the laymen's attention is mostly directed towards buildings and constructions like houses, farms, stables etc. and thus these features seem to be very important in guiding the viewing pattern. The same basic pattern, however, is found for the expert group. To detect any differences in attention between the two groups, a detailed quantitative analysis of the interest areas, drawn systematically around buildings and constructions, was performed. First, the results indicate that novices visit the interest areas as often as experts ($P > 0.05$): approximately 2 visits per interest area on average (Table 3). Since both groups seem to fix buildings after approximately 2 seconds, no difference could be found in the time at which the first interest area is entered ($P > 0.05$). Furthermore, the statistical test does not reveal any significant differences in the absolute number of fixations made in interest areas by lay people and experts ($P > 0.05$). However, the proportion of the total amount of fixations occurring in the photograph seems to significantly differ between both groups ($P < 0.05$). On average, 17.98% of the fixations made by laymen were measured within an interest area, compared to 16.47% for the experts (Table 3), which means that a non-expert observer fixates relatively more on buildings. Furthermore, non-experts seem to spend significantly more time in the interest areas (1.6 seconds on average), while experts explore the buildings more quickly (1.4 seconds on average) ($P < 0.05$). In relation to the entire viewing time (10 seconds) lay people on average spend 15.53% of the time observing buildings. For the expert group this proportion decreases to 14.55% ($P < 0.05$). The duration of the first fixation made in each interest area also indicates how strongly buildings catch the attention. The statistical analysis shows that this first fixation duration is significantly different for experts and non-experts in that the first fixation made by non-experts seems to be longer, although the difference is subtle (Table 3) ($P < 0.05$).

Table 3. Results of the Mann–Whitney U-test for the interest area-metrics (mean rank). If significantly different, maximum values are indicated in dark grey, minimum values in light grey. Recorded mean values for each ETM are given for the experts and the non-experts. N gives the number of observations.

Eye Tracking Metric	**N**	**Mean rank**		**P**	**Real mean values**	
		Experts	**Non-experts**		**Experts**	**Non-experts**
Number of visits per interest area	4,647	2,310	2,338	0.459	2.44	2.48
Entry time of first interest area (s)	2,075	1,014	1,062	0.071	2.03	2.14
Number of fixations per interest area (all visits)	4,647	2,297	2,353	0.147	5.10	5.37
Percentage of fixations that fall into an interest area (all visits)	4,647	2,270	2,381	0.005	16.47	17.98
Fixation time per interest area (all visits) (s)	4,647	2,285	2,365	0.044	1.44	1.55
Percentage of fixation time per interest area (all visits)	4,647	2,285	2,365	0.044	14.55	15.53
Duration of first fixation in an interest area (ms)	11,421	5,650	5,775	0.043	283	286

4 DISCUSSION

4.1 Interpretation of the results

4.1.1 Fixations, saccades and scan path

Duchowsky (2007) demonstrated that a larger *amount of fixations* in the same observation time increases the observer's memorization and recognition capacity. According to this theory, our findings could indicate that the memorizing capacities of landscape experts are larger than those of laymen as their higher fixation frequency enables experts to absorb and memorize more information in the same amount of time. In addition, the shorter *fixation durations* of experts indicate the ease with which the landscape photographs are processed and encoded. Former studies have pointed out that fixation duration reflects the processing-time spent on the object being fixated (Just & Carpenter, 1976), which in turn indicates the observer's difficulty obtaining information from or interpreting the given object (Duchowsky, 2007; Fitts et al., 1950; Goldberg & Kotval, 1998). In general, it has been demonstrated that images or objects associated with long fixation durations are more difficult and effortful to interpret (Henderson et al., 1999; Holmqvist et al., 2011) or are not as meaningful to the observer as objects characterized by shorter fixations (Goldberg & Kotval, 1999). Consequently, the shorter fixations of the landscape experts, found in our study, mean that the degree of expertise in landscape related topics influences the processing-time spent on the objects constituting a landscape. Landscape experts seem to process information faster and interpret and identify the landscape objects more easily and more quickly. These results confirm the findings of Mann et al. (2007) who found that expertise causes differences in gaze behaviour, which are functional in terms of more efficient information pick-up. This saves time, which enables experienced landscape observers to produce more fixations in the same 10 seconds observation period. The landscape photograph can visually be explored more intensively, increasing the experts' capacity to identify and interpret individual objects and to recognize and memorize the image as a whole. These findings are consistent with the Information-processing Theory developed by Kaplan & Kaplan (1989a). According to this theory, there are two major categories of human needs, concerning information extraction from the environment: *understanding* and *exploration*. Like all other creatures, humans want to understand their environment and what takes place in it. Kaplan & Kaplan (1989a) state that this *understanding* depends, at least partially, on prior knowledge or experience. Our findings support this and indicate an easier and faster understanding of the environment by the experts because of their larger knowledge and training. Because of this 'advantage', landscape experts can spend more time on the *exploration* of the environment and obtain a more complete and detailed idea of the landscape. In turn, this more elaborate exploration expands the accumulation of experience and knowledge and increases the capacity to understand new, formerly confusing situations and facets, which again facilitates and accelerates the understanding of the environment and so on.

Saccade-related metrics can only be used to study the search pattern (Goldberg & Kotval, 1999), as no encoding takes place during eye movements (Rayner & Pollatsek, 1989; Mann et al., 2007). According to Goldberg & Kotval (1999) more *saccades* are indicative of a more extensive inspection. Our experiment shows that participants from the expert group made significantly more saccades than the lay people ($P < 0.05$), again suggesting that experts are able to visually explore the landscape images to a larger extent. In addition, the experts seem to make smaller saccades than the laymen ($P < 0.05$). As shorter saccades take less time to plan and to execute, this leaves more time for fixations and thus for information processing (Abrams et al., 1989).
These findings are consistent with results of similar expert/novice studies in other domains, which have demonstrated an increased number of fixations and saccades and shorter fixation

durations associated with experts compared to laymen (Chapman & Underwood, 1998; Konstantopoulos, 2009; Rayner, 1998; Vogt & Magnussen, 2007). Most similar to our study is the research conducted by Vogt & Magnussen (2007), who performed an eye tracking experiment in which artists and novices were asked to freely observe paintings, ranging from everyday scenes to pure abstraction. Like in our research, the experiment revealed that the artistically untrained participants used fewer and longer fixations when inspecting the images compared to the artists, who made significantly more, but shorter fixations. This strengthens the theory that expertise reduces the time required to process domain-specific information, offering experienced people the opportunity to visually explore the images to a larger extent by making more fixations and saccades in the same amount of time.

Besides fixations and saccades, the entire *scan path* provides valuable information about how and over which distance the observer has ‘travelled’ through the landscape photograph. The scan path length, which is generally calculated as the sum of all saccadic amplitudes in a scan path, may, in combination with luminance maps (see section 3.3), provide insights into the spatial extent of the observation (Holmqvist et al., 2011). The longer scan paths found for experts suggests that the extent to which the landscape is visually explored increases with expertise. However, making this conclusion should be considered with caution. For example, when an observer divides his/her attention among a few objects and constantly moves between these objects, he or she might have a long scan path while in reality only a small proportion of the image has been viewed. Further analyses based on Voronoi cells and luminance maps are necessary to control this issue (see section 3.2, 3.3 and 4.1.2).

4.1.2 Visual span

The larger Voronoi cells found in the expert group indicate a rather dispersed pattern of fixations. For the laymen, the Voronoi cells are smaller, showing that their fixations are more clustered (Figure 4). According to the interest area analysis this clustered fixation pattern can be explained by the lay people's greater focus on buildings compared to experts'. Buildings seem to catch and hold laymen's attention much more and longer, which as a result hampers their further visual exploration of the landscape. These findings support the assumption that experts seem to have a larger visual span than lay people when visually exploring landscape photographs. This result corresponds to the holistic model of image perception, which focuses on the extension of the visual span (Kundel et al., 2007). In short, this theory proposes changes in the perceptual processes due to expertise. In particular, Gauthier & Tarr (2002) demonstrated that when observing field-specific images, experts start with an initial global viewing of the image, followed by a more detailed decomposition of the picture into hierarchical, structural components. In other words, experts seem to process such images in a more holistic fashion than non-experts. Consequently, experts' visual span tends to be larger compared to laymen, whose observational span is more restricted (Gauthier & Tarr, 2002). However, the question remains if because of this holistic viewing pattern experts also spend more time on deducing relationships between the different objects rather than of viewing individual elements like non-experts probably do. Although this hypothesis has been confirmed for artistically trained and untrained viewers, who were asked to observe a number of paintings (Nodine et al., 1993; Vogt & Magnussen, 2007), further research is necessary to determine if similar conclusions are valid for landscape experts and laymen.

4.2 Implications for participatory landscape planning and management based on visual landscape assessments

Our findings may be important for participatory landscape planning, in which different focus groups are often consulted to evaluate potential landscape changes based on landscape photographs. Such visual landscape assessment studies aim at evaluating the visible features of a landscape for purposes of management, planning or design (Palmer & Hoffman, 2001). More and more, these studies involve public judgments besides expert appraisals (Palmer & Hoffman, 2001; Selman, 2000 & 2006). Opinions are often probed using visualisations, as landscape management is inextricably linked to perception (Berlan-Darqué, 2008). Especially in the field of landscape management and planning, 'understanding' is very often equal to 'seeing' (Kaplan & Kaplan, 1989b). Moreover, people tend to make judgments based on what they see, more than on what they know. As a result, visualisations, which have been demonstrated to provide information in an understandable way, are a widely used medium when assessing landscapes (Bell, 2001). However, what people see may vary according to a number of factors. Chua et al. (2005), for example, states that differences in eye movements, memory for scenes and perceptual judgments could be caused by differences in experience and expertise. In particular, it is assumed that experts look differently at something that is presented in their "expert language" – in this case landscapes or landscape photographs – than lay persons (Lange, 2005). The reason for this phenomenon is that experts master key principles around which knowledge is hierarchically structured (Van Heuvelen, 1991). In landscape related topics, this difference in knowledge is reflected by a difference in perception: landscape professionals tend to dissect the landscape into all its constituent elements, while lay people don't (Scott, 2002). People with different backgrounds and different levels of expertise might thus look for different things in a landscape (Bell, 2001) and might consequently not see the same landscape (Bell, 2001; Meinig, 1979;

Stewart et al., 2004). As a result, judgments and opinions formed based on what has been perceived could differ as well (Bell, 2001; Chua et al., 2005). This is an important issue for visual landscape assessment studies in which landscape professionals and lay people are consulted. So far, many studies have demonstrated significant assessment differences between both groups (Bell, 2001; Godschalk & Paterson, 1999). However, almost none has reported on how the lay persons and the experts actually observed the landscape images. Neither has been checked if both groups looked at the same features in the landscape and thus formulated their assessment based on the same elements of the landscape. Our study points out that landscape experts and lay persons do perceive landscape photographs differently and as a consequence probably do not see the same landscape: while experts explore the landscape as a whole with detailed inspections of its constituting elements, lay people have a much more restricted viewing pattern only focussing on a few elements, mainly buildings. Although, we did not investigate people's opinion about the landscapes, it could be that this different viewing behaviour may lead to diverging assessments. In turn, this may cause discord and discussions which could delay or even hamper landscape development or planning. The first step to avoid this consists of better understanding assessments of different (groups of) respondents by verifying on which features in a landscape an assessment was based. This could be achieved using eye tracking, which offers the possibility to check where people consciously and unconsciously look at in a scene when making an evaluation. In addition, eye tracking results could also be used to show landscape professionals that they literally have a different view on landscapes than lay people and that this dissimilar observation pattern should be taken into account when trying to unify different assessments. This is important because nowadays most of the time experts are not aware of these different views and perceptions of the landscape (Strumse, 1996).

4.3 Recommendations for further research

While this study provides essential information about how expertise influences the observation of landscape photographs, more research should be performed to examine this topic in greater detail. In particular, two main issues should be investigated to check their impact on the results. First, the results presented in this study are valid when a limited viewing time of 10 seconds is imposed. In eye-tracking terms this is a very long exposure time and several authors have demonstrated that the gist of a scene is accurately assimilated and consolidated into memory in the a few hundred milliseconds (less than 200 ms according to Potter et al. (2002), 500 ms according to Biederman et al. (1983) and Thorpe et al. (1996)). As such, a lot of the semantic content is perceived within a single glance of a scene (Biederman, 1972; Boyce et al., 1989; Grill-Spector & Kanwisher, 2005; Thorpe et al., 1996; VanRullen & Koch, 2003). However, it is not sure that an opinion about an image is completely formed in this first half of a second. Potentially, it can change when viewing the image for a longer time when, for instance, smaller details of the image are discovered which were initially omitted. This would imply that when viewing times increase the visual span as reflected in the luminance maps would expand. Furthermore, the question raises how the luminance maps of the experts and laymen would evolve and if the difference between both would increase or decrease. We believe that these are important issues to further investigate as in landscape assessment situations time limits are very unlikely.

Second, the differences in viewing patterns between experts and laymen may to some degree be caused by the free-viewing condition. For example, it is possible that as a result of their knowledge, the experts might have performed a landscape diagnostic and as such unconsciously have created their own ‘task’. This phenomenon is less likely to occur for lay people as they are missing this knowledge. However, the creation of an own task can never be completely ruled out. While in fact this is an expression of the presence or absence of expertise and knowledge, it does not affect the validity of our results. Instead, it could offer an explanation as to why differences in perception occur. A well-known technique used to probe people's mental processes and thoughts is to apply the thinking aloud-method, in which participants are asked to tell out loud everything which crosses their mind while observing images (Nielsen, 1993; Van Someren et al., 1994). In future studies this should be used in order to identify the underlying processes which lead to different observation patterns.

5 CONCLUSIONS

In this study we investigated if expertise in landscape related matters influences the way people observe landscape photographs as this could be valuable information for understanding why landscape experts and laymen often seem to have divergent judgments when visually evaluating landscapes. Our eye tracking experiment reveals a significant difference in viewing pattern between landscape experts and lay people. Acquired educational or professional expertise with respect to landscapes seems to enhance efficient information extraction in terms of an improved interpretation, identification and understanding of landscape objects. This reduces the time required to process the information registered by the eyes, offering an expert the opportunity to visually explore the photograph to a larger extent. As a result, the main viewing pattern of landscape experts consists of exploring the landscape as a whole, with short focuses on many different elements. This is reflected by a number of eye tracking metrics, like a higher number of fixations and saccades, a longer scan path, a more dispersed fixation pattern and thus a larger visual span. In summary, landscape experts seem to observe landscape photographs in a holistic fashion, consisting of a global scanning of the image alternated with more detailed inspections of particular components. In contrast, non-experts spend considerably more time and attention to specific objects, in particular to buildings, restricting their visual exploration of the landscape.

This is reflected in a smaller amount of fixations and saccades, a shorter scan path, a more clustered fixation pattern and a smaller visual span. Unlike landscape experts, laymen's focus is mainly on singular elements in the landscape and less on the landscape as a whole. This behaviour can be a consequence of the lack of expertise or knowledge regarding landscapes, which makes longer fixations on individual objects necessary to resolve uncertainty or confusion about them and to understand their meaning. Consequently, information processing is slower, leaving less time to explore the image in the fixed test time.

These results are of particular interest for participatory landscape planning and management for which experts as well as the public are often consulted to visually assess new landscape developments. As differences in expertise influences how a landscape is observed, an expert and a lay man will not focus on the same features in a landscape and thus might not see the same content. As a result, their assessments will be based on different aspects of a landscape and might thus be very divergent. This should be taken into account when consulting different groups of respondents with diverse backgrounds for carrying out visual landscape assessments. In particular, eye tracking could be used for checking which features of the landscape have been perceived before making the assessment.

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