Using Eye Tracking to Investigate the Audio-Visual Effect of Landscape Perception: A Research Review

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Outline

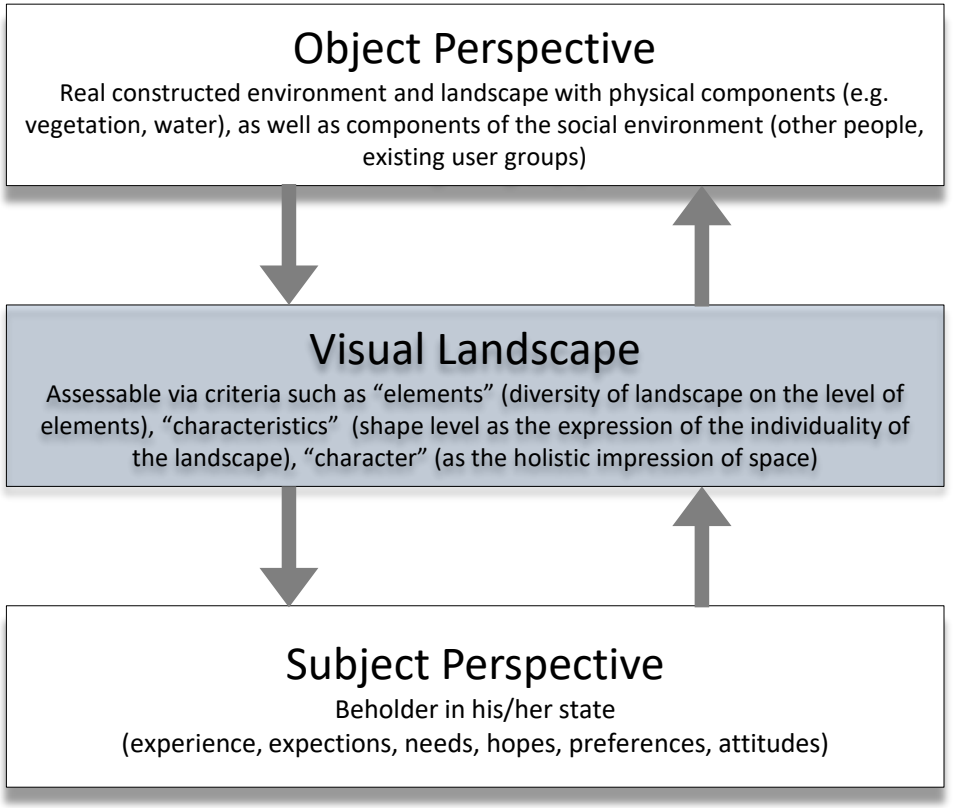
This paper reviews and summarizes the multi-sensory landscape perception research and the applications of eye tracking within this field.

1. **researches of landscape perception and the difficulties of the conventional assessments;**
2. **the use of eye tracking in studying the audio-visual effects of multisensory environment;**
3. **theories on attention and cognitive resources behind gaze patterns;**
4. **further applications and technical limits of eye tracking referring to landscape researches.**

The Objectivist and Subjectivist of Landscape Perception

The definition of Landscape:
'an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors.' (European Landscape Convention ,2000)

Perception of landscape helps us to understand and interact with our environment. Therefore, the way we perceive the landscape is always a combination of objective facts, personal memories and expectations, cultural backgrounds (Wöbse, 1982; Bourassa, 1988, 1990).

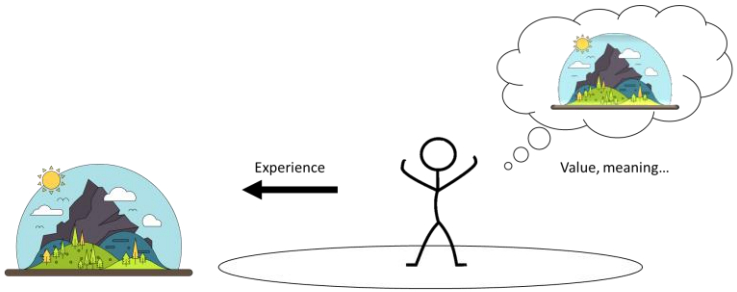


--Jessel, 2006

Landscape Representation and Multi-Sensory Integration

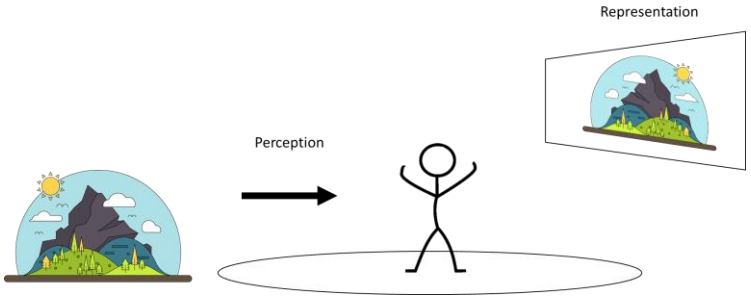
The difficulties of semantic representations of landscape perception:

- The Ambiguity/Interrelationship of Semantic Descriptions
- The Flexible Decision Criteria of Semantic Judgements



The Information needed to deal with those problems:

- The Process of Landscape Perception
- The Outputs/Representations of Landscape Perception



Landscape Representation and Multi-Sensory Integration

The Process of Landscape Perception

The Representations of Perception

The Interpretation of representation:
Landscape understanding; landscape judgement; landscape preference…

Different Sensation: visual landscape; soundscape; smellscape……

Multisensory interaction: audio-visual effects;

Structural criteria: simplicity vs. veracity

Unimodal representations vs multimodal representation

Eye Tracking as a Metrical Tool: *Perceptual Preference*

The comparison paradigm of eye tracking is the most used in preference research like typical preference judgement tasks.

Metrical Goals	Mental Properties	Measure Index (Area of Interest Based)
Measures of Attraction	noticeability	Number of fixations prior to first fixation Time to first fixation
***	**Interest**	**Number of fixations** (e.g. Wan et al., 2018; Yasui et al., 2019) **Total dwell time** (e.g. Bee et al., 2006; Brimingham et al,2009;) **Percentage of time**
	Emotional arousal	Pupil diameter
Measures of Performance	Mental workload	Pupil diameter
	Cognitive processing	Average fixation duration
	Target recognizability	Time from first fixation on target to target selection

***: used in most landscape preference researches and other design fields researches

Eye Tracking as a Metrical Tool: *Landscape Perception*

As related techniques are developing, the number of eye tracking researches refering to landscape perception are increasing and new paradigms are emerging.

Research Scenarios	Research Features	Typical Metrics	Related Literatures
Photograph-based	Merits: Easy to conduct experiments; Easy to interpret the results; Defects: Truncated experience behaviors; Result lack of ecological validity;	Number of fixations; total dwell time; fixation durations;	Brush, 1981; Nordh & Hägerhäll, 2009; Huang & Lin ,2019;
in situ field	Merits: Highly ecological validity; Suitable for exploration researches; Defects: Hard for comparison researches; Difficult to analysis and explain data;	Spatial gaze distribution; number of fixations; fixation durations; percentage of first fixation on AOI;	Foulsham et al., 2011; Cottet et al., 2018;
Immersive virtual reality	Merits: Highly ecological validity; Highly controlled settings for empirical validity; Defects: Complicated experiment settings; Lacking of analysis techniques;	Fixation density map (distribution and entropy);	Anderson & Bischof ,2019; Haskins et al.,2020;

Eye Tracking as a Metrical Tool: *Landscape Perception*

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Research Aims	Research Contents	Typical Gaze Metrics	Related Literatures
Cognitive-based	Kaplan's attention restoration theory ; prospect-refuge theory	Number of fixations; total dwell time; fixation durations;	Kaplan, 1975; Kaplan & Kaplan, 1989; Kaplan, Kaplan, & Wendt, 1972; Nordh et al., 2010, 2013; Lee, Lei, Wu, Hou, & Tzeng, 2015;
Element-based	color; pasture; water; …	Number of fixations; fixation durations; average dwell time; time to first fixation;	Jacob & Karn, 2003; Arriaza et al., 2004; de Val, Atauri, & de Lucio, 2006; Potocka, 2013; Ode Sang et al., 2014; Ode et al.,2016; Huang and Lin (2019)
Category-based	openness; heterogeneity; urbanization; …	Total dwell duration; fixation durations; total Scan path; scan length; focus map;	Dupont et al., 2014; Kim et al., 2013; Dupont et al., 2014; Dupont et al., 2016a, 2016b;

Eye Tracking as a Metrical Tool: *Audio-Visual Effects*

Oculomotor behaviours provides a window into the complex interaction between different sensory and motor systems.

Perceptual Integration	Perceptual Phenomenon	Eye Gaze behaviors	Related Literatures
Sensory & motor interaction	Visual motion aftereffects	Visual saccades (direction; frequency; etc.); nystagmus;	Paulsen & Ewertsen, 1966; Rolfs et al., 2005; Valsecchi & Turatto, 2009; Kerzel et al., 2010; Yuval-Greenberg & Deouell, 2011; Zou et al., 2012; Lusk & Mitchel, 2016; Król, 2018
Auditory & spatial localization	ventriloquist effect	Fixation (positions; durations); saccades;	Razavi et al., 2007; Pavani et al., 2008; Van Grootel & Van Opstal, 2009; Pages & Groh, 2013; Maddox et al., 2014
Audio-visual integration	McGurk effect	Smooth pursuits; fixation (positions; durations); pupil reactivity;	Xiao et al., 2007; Ren & Kang, 2015; Braga et al., 2016; Liu et al., 2019

Gaze Behaviors and Attention Theory

Landscape

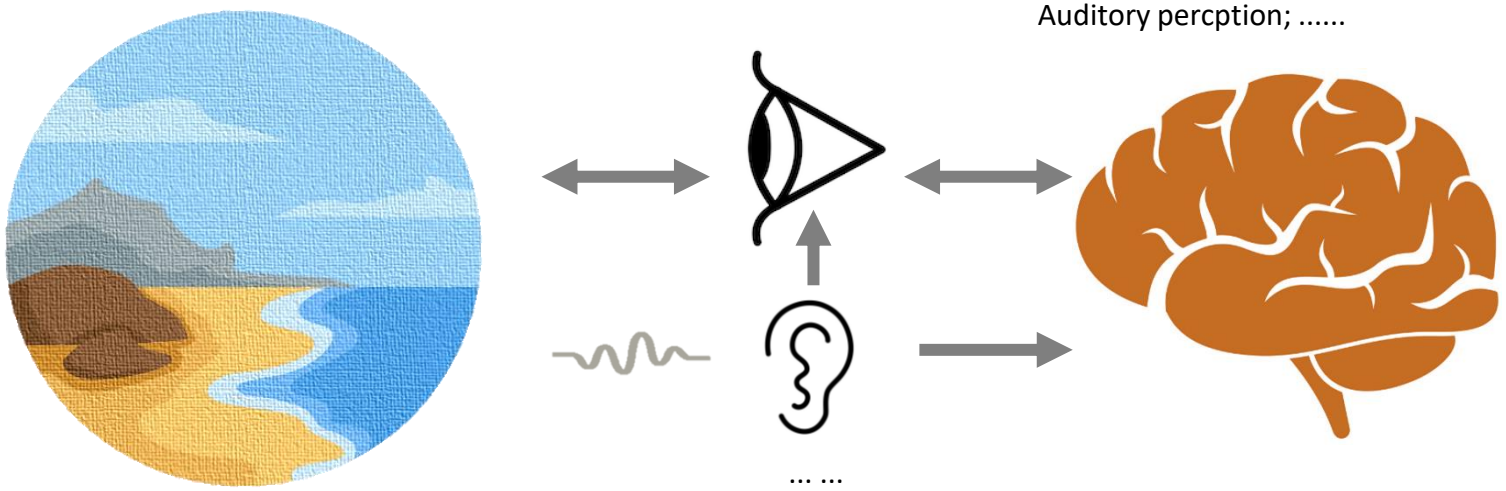
Color; Contrast; Edges; Chromatic…

Gaze Behaviors

Fixations; Saccadic distribution;...

Landscape Perception

Foveal vision; Peripheral vision; Auditory percption; .....



… …

Attention Theory

The cognitive process: **What** (objects & scene), **How** (Spatial & Temporal selection), **Why** (endogenous & exogenous)
The computational models: **saliency** maps; attention DL networks;

Pupil Metrics and Cognitive Load

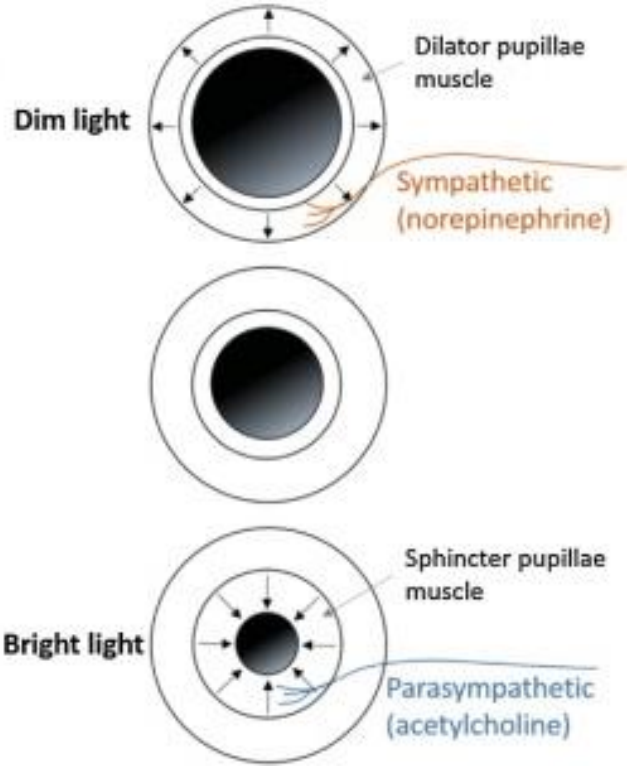
Pupil metrics is the measurement of pupil diameter while cognition proceed.

Cognitive Load Theory (CLT): related to human ergonomics and performance

— Hess and Polt (1964): pupil diameter increases with task difficulty.

— Marshall (2000): the Index of Cognitive Activity (ICA)

— Duchowski et al. (2018) : the Index of Pupillary Activity (IPA)



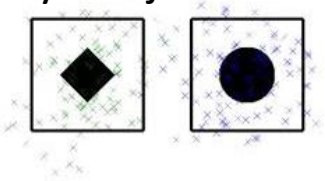
From Eckstein et al. (2016)

Eye Tracking: Limitations and Further Applications

Eye Tracking Analysis Hypothesis

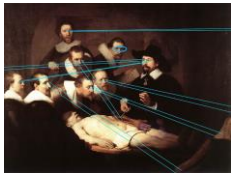
Eye-mind hypothesis (EMH)

Eye-object assumption



Complexity of behavior explaination

Lacking of contextual information



Multimodal methods

mental state measurements
(EEG; fNIRS; EMG; etc.)

Complex decoding & cross classification
(deep neural networks; representational similarity analysis; etc.)

Multisensory environment simulation

Immersive Virtual Reality (IVR)

Conclusions

In a multisensory landscape environment, vision and hearing both interacts through the "what" and "where" pathways in a temporal-spatial context to form a sense/perception of the place.

Eye gaze behaviors can provide the perceived contents and their relationship for investigation the **process** and **presentation** of landscape perception in a **multisensory** view.

Combined with a **full-stimuli** controlled environment such as Immersive Virtual Reality, gaze behaviors give us not only the information of visual inputs, but also a **real-time** and **interactive** feedback of human in landscape environments.

It is helpful for the researchers to understand the mechanism of human perception in complex contexts and the designers to manage landscape settings for human wellbeing.

thank you for your attention