A Review on the Application of Eye-tracking in Design Areas

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Objective: This study aims to examine domestic literature on eye-tracking in the design area, and to present new eye-tracking application directions.

Background: Eye-tracking was introduced in the experimental psychology field for the first time in the 1950s. Eye-tracking has high utilization values in the design application area because eye-tracking can accumulate data on what people see, providing the quantitative values on eye movement.

Method: This study examined the papers published in domestic journals, as well as the papers presented in conferences from 2000 to 2016 through DBPIA.

Results: Although the use of eye-tracking technology was slightly meager in the product design area, it has been actively used for the evaluation analyses of preference and attention in architecture/public design. Eye-tracking also presented a method to design advertisement that is helpful to advertisement effect measurement, and product salesin the advertisement design area. Since detail psychological analysis is possible, the application of eye-tracking in the studies related with user interface has been active.

Conclusion: The eye-tracking technology is projected to be actively used as a new interface means, such as in helping in disabled people's communication and in device control, in addition to conventional application areas.

Application: This study would be of help to find future research areas of eye-tracking.

Keywords: Eye-tracking, Design, Review

1. Introduction

Humans pay attention to perceive an entity/individual in which they are interested in the visual environment and respond to it. In particular, a visual response to an object, which a human is interested in and pays attention to, is revealed (Kim and Kim, 2016). Gaze is the direction of an eye observing a visual stimulus, and the movement of eye means moving the eye from one object to another object. If the movement of the eye is observed, a human's gaze characteristics can be understood; that is, what, how, and how long a human observes, along with psychology that becomes the background, can be tracked. However, it is impossible to directly observe and identify eye movement with the naked eye. A technology enabling the direct observation of eye movement through a machine is called an eye-tracking technology. It is also

known as gaze tracking in that gaze is measured by observing the movement of gaze. This is also known as eyeball tracking and pupil tracking.

An attempt to observe a person's gaze and estimate the person's psychology has a long history. Although attempts to check the movement of the eyeball through afterimage or the number of eyeball movements continued, they were just the confirmation of simple movement, rather than actual gaze measurement (Kim, 2014). Since then, scleral search coil and Purkinje imaging have been developed, and actual eyeball movement measurement has become possible. At present, video-based eye-tracking using image processing is mainly used. Here, the movement of the pupil is detected, and the direction of the gaze is calculated based on the fixation direction reflected on the cornea through real time camera image analysis.

Eye-tracking was introduced in the experimental psychology area for the first time in the 1950s, and it placed itself as a method to measure and analyze attention level in the 1970s. In actuality, eye-tracking is diversely utilized in airplane navigation equipment and in traffic and arts areas (Park, 2010). Specifically, direct data accumulation on what an experiment subject is currently looking at is possible, and quantitative value on eye movement can be identified. Therefore, eye-tracking has high utilization value in the design application area.

In this study, how eye-tracking technology was applied in the design area, after its introduction in Korea, was examined. This study investigated literature that utilized eye-tracking in the design application area, classified it by utilization area, and arranged the value and limitation of studies. Also, this study presented a new eye-tracking application method in the design area.

2. Method

This study, as a literature study, examined the papers published in journals and the papers presented in symposiums/conferences from 2000 to 2016 that are among the domestic data of the DBPIA. The reason is that there were almost no studies related with eye-tracking in Korea before 2000, and the technological level before 2000 was much different from that of the present. Therefore, literature before 2000 was excluded from the examination subject.

Search was made using the following search keywords: eyeball tracking, eyeball movement, eyeball movement tracking, eyeball movement, eye-tracking (tracker), pupil tracking, movement of pupil, gaze tracking, and derivative combination. The searched data were 365 cases in total. For the analysis subjects, this study selected 56 studies utilized in the design application area. Upon looking at 56 papers from the order of publication year, most started to utilize eye-tracking in the design area from the latter part of the 2000s, with research actively carried out from 2010.

3. Results

If gaze at a design is tracked through eye-tracking, quantitative data on the visual characteristics of the design can be acquired, and a user's psychology, including satisfaction and preference, can be tracked. Therefore, this study conducted active research on eye-tracking in various design areas. There were studies on the evaluation of architecture and indoor design, public environmental design, and UI design, as well as product design. There were also studies on development as HCI meant to control systems using eye gazing. In the advertisement area widely known as eye-tracking utilization area, eye-tracking is used for advertisement effect measurement and the conveyance of meaning.

3.1 Product and environment design

This study divided designs into product area with hardware-like tangible characteristics (Table 1), architecture design of building

and indoor (Table 2), and public design (Table 3) to which public places, traffic environment, or landscape belongs.

There were studies on a product's psychology and gazing characteristics like a study on premium product design elements (Lee and Shim, 2015), a study on the emotional touch point analysis of automotive interior space (Seo and Choi, 2014), and a study

Table 1. Applications on product design

Title	Author	Year
A Study on emotional touch point analysis by Eye-Tracking technology in dynamic environment - Focused on automotive interior space -	Seo and Choi	2014
Eye Tracking User Research for Comparative Advantage Analysis of Premium Design Elements	Lee and Shim	2015

Table 2. Applications on architecture

Title	Author	Year
The Characteristic of User Preferences Considering Kiosk Design Development - Focused on People Waiting for The Treatment of Pediatric Hospital	Choi and Park	2012
A Study on the Interest of the Eyes Applying Gazing Phenomena - Based on an Eye-tracking Experiment Carried with a Facade as a Medium	Yeo and Lee	2014
A Study on the Perceptional Characteristics of Facade Image of Single Home - Based on the Experiment of Perceptional Characteristics in respect to Eye Movement Tracking -	Cho	2015
A Study on the perceptional Characteristics of Facade Image of Single Home by the Change of Level	Cho and Jeon	2016
An Analyzed the Area of Interest based on the Visiting Intention through the Spacial Eye-tracking	Kim and Kim	2016

Table 3. Applications on public design

Title	Author	Year
A Study on Driver Behavior in LED Lamp Install Tunnel Section	Park and Park	2006
A Basic Study for Evaluating Visual Attention about Public Environment Facilities Affording Wayfinding - Focused on Eye-tracking Methods -	Park	2008
Older Drivers' Characteristics and Optimal Number of Guide Names on Road Signs	Noh et al.	2008
A Study on Evaluating Visual Attention of Public Environment Facilities in Subways by Using Eye tracking Method, Archives of Design Research	Park	2010
A Study on the Relationship between the Characteristics of Visual Perception and the Visual Preference - focusing on the beautiful spot sceneries designated by Seoul City	Suh and Park	2011
A Study on Characteristics of Visual Fixation in an Evacuation Process Created via Virtual Reality - Focusing on Subway Evacuation Simulation	Kim and Ban	2013
A Study on Driver's Gaze Area in Variable Road Characteristics Using Eye Tracking System	Park and Kim	2013
A Study on the Priorities of Urban Street Environment Components - Focusing on An Analysis of AOI (Area of Interest) Setup through An Eye-tracking Experiment -	Lee and Lee	2016

on visual percentile by vehicle to evaluate a vehicle's visibility, all of which focus on product design. Among those studies, Seo and Choi (2014) conducted emotion analysis of automotive interior space using eye-tracker to complement the limitations of emotional research that was originally analyzed by linguistic expressions.

Yeo and Lee (2014) in the architecture design area conducted an eye-tracking experiment under the medium of image on the linking line of a shop's indoor and outdoor spaces, and they studied the interest of eyes derived from a human's attention phenomenon. This study presented a new methodology by combining a consumer's eye movement and his/her status of interest. In relation with the public environment, landscape evaluation was carried out by mainly linguistic means of psychological evaluation so far, and thus interpretation was made by the researcher's judgment and experience without absolute evaluation criteria. However, the experiment subject's visual response could be observed and applied through eye-tracking (Suh and Park, 2011). A study on a driver's gazing point or area change analysis upon driving on the road and then utilizing the results for the plan or design of roads and road facilities (Park and Kim, 2013), or a study on LED lamp installation helping traffic safety in the tunnel section (Park and Park, 2006) is worthy of attention.

3.2 UI design

In relation with User Interface (UI) design, designs can be divided into studies on multimedia Web service (Table 4), virtual reality (Table 5), and mobile device interface designs (Table 6).

In the Web design area, Hong (2014) presented infographics service direction to the press by comparatively analyzing through eye-tracking experiment and in-depth interviews on the infographics service usability of Chosunilbo and Maeil Business Newspaper. However, it is a limited study in that the study compared entire infographics with relatively simple interviews, while the experiment participants were only five people.

Table 4. Applications on web design

Title	Author	Year
Development of Integrated Analysis Model and Tool for Web Usability Test - with Emphasis on Eye - Tracking, Mouse - Tracking, and Retrospective Think Aloud	Kim and Lee	2007
The Comparison Studies of Infographics on Chosunilbo and Maeil Business Newspaper - Mainly with Users's Eye Tracking Analysis	Hong	2014
An Evaluation of University Library Sites Based on Eye Tracking	Kang et al.	2015

Table 5. Applications on virtual reality

Title	Author	Year
A Study on the Screen Layout of Virtual Character through Eye-tracking	Kim and Jeong	2008
Comparative Analysis of Users' Cognitive Differences in MMORPG Interfaces	Kim	2008
The Effects of Information Transmission in Lectures Using a Virtual Studio: With Analyses Focusing on the different lecture templates and materials	Bae et al.	2008
A Study on the Fixation point Analysis of Virtual Character by Eyetracking	Kim	2009

Table 6. Applications on mobile design

Title	Author	Year
Usability Test by Integrated Analysis Model - With Emphasis on Eyegaze Analysis of Mobile Interface Design -	Sung and Lee	2004
Usability Test of Mobile Interface Design with Eyegaze Equipment	Sung and Lee	2004
User's Behavior of Touch-screen Mobile Phone using Eye Tracker	Kang et al.	2009
A Study on the Optimization of the Digital Media Service Menu Structure based on the Differentiations of User Experience with: special reference to Eye Tracking Test	Lee	2010
Visual Patterns and Performance Evaluation in the Scrolling Design of a Mobile Information Device	Kang et al.	2010
A Study on interface Design Model from the Eye-tracing of Visual consciousness - Focus on Interface of Navigation Device	Jang	2011
Eye-catching colors analyzing eye movement path	Baik and Suk	2011
Usability Evaluation of NTIS-NDSL Service 'R&D' Navigator'	Yu et al.	2013
User Interface Evaluation Method For Mobile Contents Using Eye Tracking	Sim et al.	2014
A study on viewing patterns in a mobile Grid View	Jung and Hwang	2014
The effects of word-by-word touch feedbacks for virtual keyboards	Kim et al.	2016
Eye-tracking Study of e-Magazine Published with Cinemagraph Images	Park et al.	2016

In the virtual reality area, these were the following studies: design direction study for game interface usability improvement through a comparative analysis of an online game's interface components' designs and layouts (Kim, 2008), strategy deployment of screen components centered on virtual characters within the virtual environment for effective information delivery (Kim and Jeong, 2008), gazing point analysis of a virtual character's design components (Kim, 2009), and lecture screen composition guideline presentation according to the change of background templates and lecture aiding materials (Bae et al., 2008).

Studies on the interface design composition and usability evaluation of mobile devices were 12 in total, and most studies were carried out in the UI design area. Also, the UI design area is expected to be a major utilization area for eye-tracking in the future. Yu et al. (2013) evaluated the usability of navigation devices by carrying out an eye-tracking and preference survey together. A survey of more detailed acceptance according to experiment subjects' types is needed.

3.3 Advertisement design

In the advertisement area, studies can be classified according to information-delivering media: they can be divided into traditional paper advertisement (Table 7), image advertisement (Table 8), and advertisement on the Internet (Table 9).

In paper advertisement, eyeball movement tracking was utilized in a scientific measurement method of the newspaper advertisement exposure effects through a comparison of readers' attention amount and memory effects when they read a newspaper (An et al., 2007). Yeo et al. (2015) carried out an eye-tracking experiment based on user evaluation in order to improve the legibility of a signboard—an advertisement board.

In the image advertisement, there were studies on eye-tracking on the configuration mode of home shopping video aiming at

Table 7. Applications on advertisement design

Title	Author	Year
An Eyetracking Study on the Measurement of Newspaper Advertising Exposure Effects: Comparison with Data Collected by Recognition Measurement	An et al.	2007
A Study on Legibility of Signboard Images of Commercial Buildings Using Eye-tracking Technique	Yeo et al.	2015

Table 8. Applications on media advertisement design

Title	Author	Year
The Influence of Nonverbal Elements of Woman News-casters' over Users News Attention and Memory Recall	Kwon	2010
The effects of arousing content and individual difference on processing of visual information from entertainment video: Measuring effectiveness of product placement with an eye tracking device	Park and Oh	2011
Eye Movement and Recall of Consumers in Patriotism-appeal Advertisements: Focused on Eye-tracking	Lee et al.	2012
Eye tracking studies on image composition method of CATV home shopping programs	Kang	2013
An Exploratory Study on the Measurement of the effect of PPL using Eye Tracking	Jeon and Park	2014
The Influence of PPL's Expression Type and Audience's Characteristics on Advertising Effects	Lee et al.	2014
A Study on the Consumer-oriented Image Compositions for Providing Information in TV Home Shopping	Lee et al.	2015

Table 9. Applications on internet advertisement design

Title	Author	Year
An Investigation of Banner Ad Effects Using Eye Tracking: An Explorative Observation	Choi et al.	2004
Feasibility Study of Elaboration Likelihood Model (ELM) on Interactive Marketing Communication: through measures using the Eye-Tracker and surveys with the Twitter	Kim and Shin	2012

selling and publicizing products, and studies on eye-tracking technology utilization on an image advertisement's objective effect measurement (Lee et al., 2015). Product Placement (PPL), a representative indirect advertisement, is a marketing technique indirectly advertising products or brand images by naturally making those appearing on various contents such as movies and dramas. Jeon and Park (2014) confirmed future PPL's effects by measuring PPL's effects with visual attention level utilizing eye-tracking within actually broadcasted programs, helping to prepare guidelines for effective PPL planning.

3.4 Interface means

The studies to use eye-tracking technology as an interface means for interaction between humans and computers are summarized in Table 10.

Table 10. Applications on interface design

Title	Author	Year
Eye Gaze for Human Computer Interaction	Kwon et al.	2003
3D View Controlling by Using Eye Gaze Tracking in First Person Shooting Game	Lee et al.	2005
A Study on the Indirect Interface Control System of the Automatic Extraction of the Eye Region followed by the Gaze Tracing	Kim et al.	2008
An Eye Mouse System Using an Infrared Illumination Camera	Kim et al.	2009
A Study on the Control System Using Real-Time Gaze Tracking and Hand Motion Recognizing	Park and Lee	2012
Personal Interface Control using Eye-Gaze Tracking and Machine Learning	You et al.	2014
Personalized Control System using Eye Tracking and SVM Classifier	You et al.	2016
Selection Method by using Gaze Tracking and Gesture Recognition for Occlusion of Virtual Object	Oh et al.	2016

Until the latter part of the 2000s, studies to control systems with only the movement of pupils were mainly conducted. Since 2010, studies on control systems combining various cutting-edge technologies, such as hand motion recognition and machine learning, together with eye-tracking have been carried out.

Lee et al. (2005) presented a method manipulating a game character's gazing direction by a pupil's movement in the 3D first person shooting game to increase interest in and commitment to the game. You et al. (2016) used hand motion recognition and eye-tracking together for the precise selection of virtual objects in the commitment virtual environment. They suggested a method to present a virtual window by quickly setting up an interest area through eye-tracking and reconstituting overlapped virtual objects via hand motion recognition.

4. Conclusion

This study systematically collected domestic studies that applied eye-tracking technology to design area, classified according to detailed area, and analyzed the eye-tracking's utilization value in the design application area. In the product design area, this study found that the utilization of eye-tracking technology was relatively weaker than in other design areas. This can mean that eye-tracking application is limited since ergonomic aspects like convenience or safety in use is also important although the attraction of external appearance is important in product design.

Eye-tracking was actively used for the preference and attention evaluation analyses of architecture/public designs. Through studies on roads and the surrounding environment, eye-tracking presented basic theory helpful to traffic accident prevention and safety. Evaluation on landscape became possible as data on gaze acquired through eye tracker became the objective evaluation indicator. Since architecture/public designs are huge in scale, pre-evaluation on virtual space is preferred to the evaluation through actual size prototype. Therefore, the utilization of eye-tracking is projected to be more activated in the future.

In the studies on User Interface (UI), the utilization of eye-tracking was active; namely, eye tracker was used as an indicator evaluating the configuration and usability of interface design, or studies utilizing eye-tracking and related technologies as an interface means of control system were carried out. If eye-tracking is actively applied to the interface evaluation of a situation in which external environment rapidly changes (i.e., driving a car) or a situation in which a similar situation lasts for a long time (i.e., control room of a nuclear power plant), it will be of help to system safety improvement. However, the common thing among studies related

with eye tracker was that an experiment was conducted through virtual images within a laboratory since data were collected by wearing equipment, and the number of experiment subjects was limited.

The eye-tracking technology is projected to be actively used as a new interface means such as helping in disabled people's communication and serving as a device control. If the combination of eye-tracking and various technologies is used as an interface means in order to further increase commitment to a game and interest in the game area, it is expected to be helpful to the game industry's development. Lastly, the digital area with strong qualitative aspect can be complemented, if eye-tracking technology is used, because quantitative and scientific design guidelines can be produced.

Acknowledgement

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