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A Content Analysis of the Trends in Vision Research With Focus on Visual Search, Eye Movement, and Eye Track

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Objective: This study aims to present literature providing researchers with insights on specific fields of research and highlighting the major issues in the research topics. A systematic review is suggested using content analysis on literatures regarding "visual search", "eye movement", and "eye track".

Background: Literature review can be classified as "narrative" or "systematic" depending on its approach in structuring the content of the research. Narrative review is a traditional approach that describes the current state of a study field and discusses relevant topics. However, since literatures on specific area cover a broad range, reviewers inherently give subjective weight on specific issues. On the contrary, systematic review applies explicit structured methodology to observe the study trends quantitatively.

Method: We collected meta-data of journal papers using three search keywords: visual search, eye movement, and eye track. The collected information contains an unstructured data set including many natural languages which compose titles and abstracts, while the keyword of the journal paper is the only structured one. Based on the collected terms, seven categories were evaluated by inductive categorization and quantitative analysis from the chronological trend of the research area.

Results: Unstructured information contains heavier content on "stimuli" and "condition" categories as compared with structured information. Studies on visual search cover a wide range of cognitive area whereas studies on eye movement and eye track are closely related to the physiological aspect. In addition, experimental studies show an increasing trend as opposed to the theoretical studies.

Conclusion: By systematic review, we could quantitatively identify the characteristic of the research keyword which presented specific research topics. We also found out that the structured information was more suitable to observe the aim of the research. Chronological analysis on the structured keyword data showed that studies on "physical eye movement" and "cognitive process" were jointly studied in increasing fashion.

Application: While conventional narrative literature reviews were largely dependent on authors' instinct, quantitative approach enabled more objective and macroscopic views. Moreover, the characteristics of information type were specified by comparing unstructured and structured information. Systematic literature review also could be used to support the authors' instinct in narrative literature reviews.

Keywords: Systematic review, Content analysis, Visual search, Eye Movement, Eye track

1. Introduction

A literature review will provide researchers with insights and will highlight the major issues on specific fields. A literature review can be classified as "narrative" or "systematic" depending on its approaches in structuring the research. While narrative review describes state-of-the art study fields and discusses relevant topics, systematic literature review adopts explicit structured methodology to improve reliability and accuracy (Cipriani and Geddes, 2003). However, since literatures on a specific area cover a broad range, narrative literature reviewers can give more or less weight on specific issues inherently (Green and Hall, 1984; Mulrow, 1987). On the contrary, a systematic literature review quantitatively observes macroscopic research trends and enables supporting and verifying authors' insights (Rhie et al., 2013).

Content analysis is a technique that quantitatively extracts meaningful information from any types of data including text, image, and video (Downe-Wamboldt, 1992). As it facilitates an in-depth exploration of the data, a reviewer can find issues through content analysis (Morgan, 1993). There are two different approaches. While qualitative content analysis generates an encoding rule form the collected data to interpret the patterns of the codes from the result, quantitative content analysis applies preexisting algorithm only to the present numerical result (Morgan, 1993).

In this study, qualitative content analysis is applied on literatures of the "vision" research area. In the encoding process, we followed an inductive category development process (Mayring, 2001) in order to figure out the current status and trend of researches. Since studies on "vision" cover the physiology as well as psychology field, the existing narrative review papers narrowed their scope to a certain period (Cavanagh, 2011; Kowler, 2011) or confined subjects to specific issues such as "visual search" or "eye movement when reading" (Koch and Ullman, 1987; Rayner, 1998). We aimed to analyze the meta-data of literatures retrieved with three search keywords: visual search, eye movement, and eye track. Through systematic literature review, we could suggest the trend of the study in the objective and macroscopic view. Moreover, we observed the significant difference between the characteristics of the information. Unstructured information was composed of title, abstract, and keywords, while structured information contained keywords only.

2. Method

Content analysis is a methodology that enables systematic approach on various types of information (Downe-Wamboldt, 1992). In quantitatively analyzing qualitatively expressed data, the importance of each concept is indirectly inferred by the relative words' frequency (Kondracki et al., 2002).

The research process sequentially follows the order 1) data collection, 2) preprocessing, and 3) content analysis, as shown in Figure 1.

2.1 Data collection

In this paper, the meta-data of 3,000 articles were retrieved from Science Direct (http://www.sciencedirect.com) and Scopus (http://www.scopus.com) from each search keyword (visual search, eye movement, and eye track). The top 3,000 articles were sorted through the Sciverse sorting criteria (ScienceDirect, 2012). While structured information contained keyword information, unstructured information collected title, keyword, and abstract information in the form of natural language. Papers published in all periods (January 1825-February 2013) and the recent five years (January 2009-February 2013) were collected.

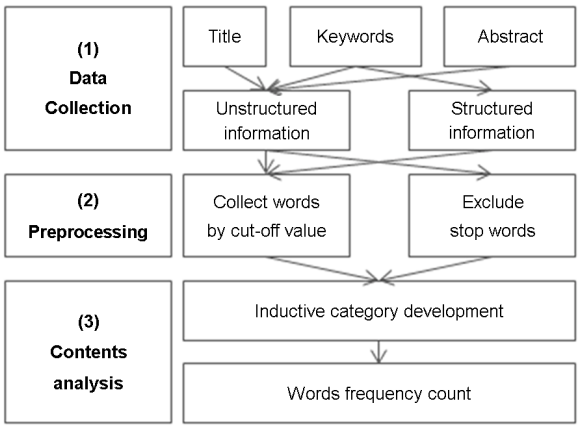

Figure 1. Flowchart of content analysis

2.2 Preprocessing

To conduct a preprocess on unstructured information, terms in plural form were converted into singular form, and stop words such as prepositions and articles were removed. Cut-off values, which are shown in Table 1, were set to ignore terms mentioned less than 20% of the collected words. In other words, only 80% of the collected words were subjected to further analysis.

Table 1. Cut-off value for unstructured data (unit: frequency)

Era	Search keyword	Cut-off value	Screened words
All	Visual search	31	1,707
	Eye movement	33	2,092
	Eye track	20	3,182
Recent (January 2009-February 2013)	Visual search	33	2,102
	Eye movement	30	2,308
	Eye track	13	3,193

As to the structured information, keywords mentioned less than two times were removed. Table 2 shows the volume of remaining literatures and their keywords, which are much decreased compared to their initial status due to errors or format.

2.3 Content analysis

After preprocessing, inductive categorization procedure (Mayring, 2001) was applied. Similar terms were grouped by instinct, deducting small groups such as object, experimental environment, level, and so on. Afterwards, groups having similar characteristics were merged until seven groups remained. Deducted categories were demonstrated in <Table 3>. "Stimuli" was defined as the object presented to participants, and "condition" represented the level of stimuli or surrounding environment. "Physiological system" was composed of terms on body parts. While eye movement behavior indicated the observable reaction of an eye mechanism, "cognitive process" denoted a process which was invisible. Measuring tools or measured features were included in "estimate", while characteristics of participants were classified as "participants".

Table 2. Cut-off value for structured data (unit: frequency)

Era	Search keyword	Volume	Screened words
All	Visual search	1,951	580
	Eye movement	1,933	529
	Eye track	1,573	356
Recent (January 2009-February 2013)	Visual search	2,742	647
	Eye movement	2,238	677
	Eye track	1,366	289

Table 3. Deducted categories

Category	Definition	Example
Stimuli	Visual subject or acoustic cue given	Reading 3D
Condition	Levels of stimuli such as size, contrast, and environment	Depth Dual
Physiological system	Neurological or physical organs or mechanism	Oculomotor Retinal
Eye movement behavior	Physical eye movement which is observable	Saccade Gaze
Cognitive process	Psychological effect or adaptation by eye movement	Attention Prediction
Estimate	Features that can be measured	Camera Eye position
Participants	Participants' characteristics or condition	Driver Infant

3. Results

The proportion of each category within papers published in all the periods and the last five years are presented in Figure 2 and Figure 3. We could observe the significant difference between unstructured and structured information, and the research trend of each search keyword.

3.1 Comparing unstructured versus structured data

Categorical distributions on structured and unstructured information were significantly different in each search keyword (visual search: $\chi^2 = 1968.460$; $p<0.001$, eye movement: $\chi^2 = 431.929$; $p<0.001$, eye track: $\chi^2 = 462.509$, $p<0.001$). Unstructured data contained terms related to "stimuli" and "condition" mostly in any search keywords. They revealed the importance of designing experimental tasks and environments in vision research. Structured data had relative importance on "eye movement behavior" and "cognitive process", showing keyword information focus on the research object rather than the experiments conducted. In addition, structured information reflected research trend more sensitively. While frequency on "cognitive process" increased the most in both data types, unstructured information showed a 2.270% increase while structured information showed a 5.392% increase.

3.2 Trend analysis on each search keyword

In general, there was a statistically significant difference in categorical distribution within the collected period as Figure 3 shows (visual search: χ^2 = 161.894; p<0.001, eye movement: χ^2 = 255.076; p<0.001, eye track: χ^2 = 161.894, p<0.001). Studies on "vision

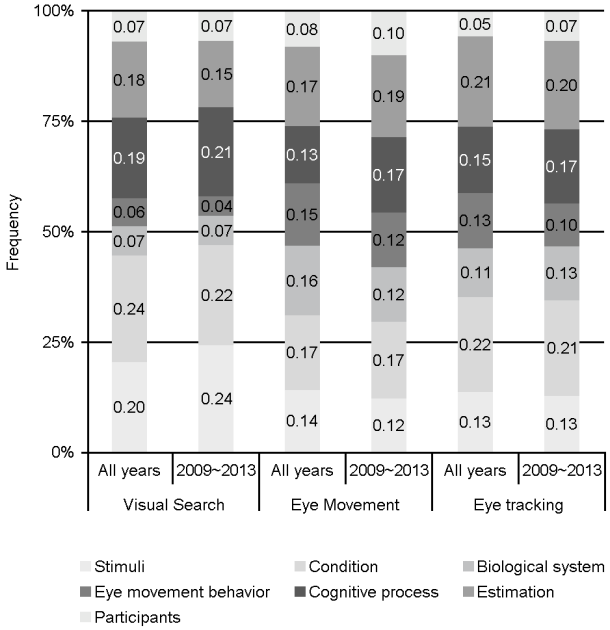

Figure 2. Word frequency on unstructured data

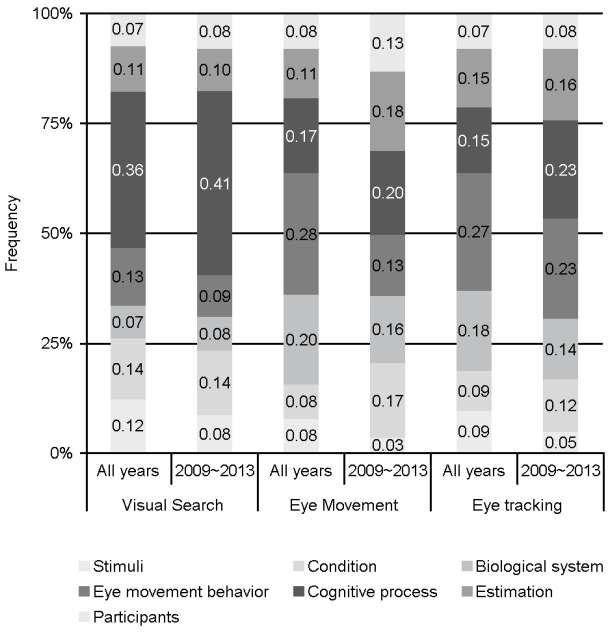

Figure 3. Word frequency on structured data

search" contained keywords on "cognitive process" mostly, while "eye movement" and "eye track" mentioned "eye movement behavior" more. On a whole, the proportion of "cognitive process" increased 5.392% while the proportion of "eye movement behavior" decreased 7.501% on average. This phenomenon showed that recent studies had interdisciplinary approach, trying to figure cognitive mechanism based on the past studies of physiology and neurology. Terms on "condition" as well as "estimation" increased 3.913% and 2.604%, respectively, suggesting that technological development enabled experiments in more varied contexts using advanced tools.

4. Conclusion

In this paper, we proposed content analysis based on the meta-data of literatures, and applied the procedure on the vision research papers. While conventional narrative literature reviews were largely dependent on authors' instinct, quantitative approach enabled more objective and macroscopic views. Moreover, the characteristics of information type were specified by comparing unstructured and structured information.

The categorical proportion of each data type was significantly different. While structured information revealed the importance of "stimulus" and "condition", structured information focused on "eye movement behavior" and "cognitive process" regardless of search keywords. This showed that the unstructured data explained entire experiments while structured information revealed research objects. Therefore, structured information sensitively reflected research trends in chronological analysis.

In trend analysis, we could observe that technological progress enabled experiments to be conducted under more varied environments. In addition, studies on physiology and psychology were converged, as literatures identifying cognitive process by observing eye movements increased in the last five years.

5. Discussion

By applying quantitative approach in literature review, we tried to point out research trends without subjective bias. However, we had limitations that three search keywords (vision search, eye movement, and eye track) could be not enough to cover the whole vision research study area, and that the literatures were collected from a confined database. Moreover, as subjective bias can interfere in the categorization process (Lincoln and Guba, 1986), the examination of more reviewers would be needed.

Despite its limitation, a systematic literature review enabled us to observe various aspects of the interest area. Network analysis also can be adopted, specifying the role and structural importance of each keyword. Systematic literature review also could be used to support the authors' instinct in narrative literature reviews.

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