Cortical Activity of Relevance

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Abstract. Many theoretical approaches in information retrieval assume that relevance is based on mutual interaction of the system and user. Past studies have mainly focused on the system side of relevance, while user-centred studies are more recent. As a result, this work aims to focus on user relevance, which is characterised as a subjective process, dependant on the specific user mind state [19]. To gain a better insight into the nature of this internal and subjective process, it is crucial to examine the underlying behavioural, physiological and psychological mechanisms involved [1]. With the development of brain imaging, new research has begun to investigate user relevance by analysing neural brain activity. However, despite the available research, different strata of relevance proposed by Saracevic (1997), have not yet been investigated in terms of neuroscience. A better understanding of relevance is an important step towards improving personalisation in the information retrieval process.

Keywords: relevance, EEG, information retrieval, information processing, cognitive relevance

1 Introduction

The main goal of the information retrieval (IR) systems is to retrieve relevant information or information units that would help users to satisfy their information need and to achieve the search task goal [7]. Relevance is a central notion in the IR [9] and it plays a key role in the user-system interaction. Additionally, relevance is an important indicator of IR systems effectiveness and performance [15, 16].

However, despite the significance and importance of this concept [17], relevance is still not completely understood [9]. In addition, relevance is difficult to define [17] and the terminology has not been consistent. Different authors assigned different meanings to the concept [10], aiming to develop an ideal and widely accepted relevance model. Nevertheless, up to date, a universal theory of relevance does not exist. Instead, many competing theories and models have been

proposed, involving different relevance criteria and several distinct components [13, 20].

The main objective of this work is to contribute to the empirical evidence associated with Saracevic's model and to increase the understanding of relevance. This work will focus on a single theory to investigate relevance while maintaining conceptual consistency during empirical evaluation. Since Saracevic's stratified model of relevance has been identified as a framework which is complex enough to consider all significant relevance aspects, yet flexible and abstract enough to be empirically tested an applied [20]. Also, his model proposes that the information retrieval process results from a set of interactions between user and system. Thus, both user and system are represented by a set of layers that are interdependent [15], allowing us to focus on the user aspect of relevant within this model.

The rest of this paper is organised as follows. First, we describe the background in Section 2, which outlines the concept of relevance and related work in the area of neuroscience.Section 3 discusses the methodological approach this work aims to employ. The current stage of the PhD progress and next planned steps will be also explained in this section. Finally, Section 4 presents key conclusion and potential implications of this work.

2 Background

This section outlines Saracevic's stratified model. It has been argued that relevance depends on the users subjective judgement [17] and hence it might be difficult to measure. Hence, this section will address how the employment of brain imaging techniques helped to tackle this problem and the findings of previous studies investigating users neural processes during relevance judgement will be summarised.

2.1 The Concept of Relevance

According to Saracevic's stratified model of relevance, IR is seen as an interaction between several layers or strata through an interface at a surface level. Relevance is therefore derived as a result of interaction among these strata [14–16]. Within this model, there are two main elements a user and a system. The user usually expresses the subjective information need (IN) through query formulation. The system then presents the user with retrieved information (system relevance), which then users interprets and relate to the problem at hand, cognitive state, and other aspects. In other words, the user retrieves information based on subjective relevance criteria (user relevance). According to Saracevic (1997), both, user and system side consists of several levels. The user side, which is the main interest of this work, is composed of cognitive, affective and situational level [14]. However, it is important to note that one of the main limitations of this model is that the model is not detailed enough for experimentation and verification [15]. However, Weigl and Guastavino in [20] discussed models potential application and usefulness in user-centred music information retrieval research.

Investigating the role of different strata during relevance judgement constitutes a complementary and promising technique which can enhance the understanding of this complex process. This work aims to do so through the employment of neuroscientific approach. The study is based on the premise that user relevance is inter-subjective, systematic and measurable in its nature, as proposed by Schamber and Eisenberg in [18]. The above-mentioned premise has been recently supported by empirical evidence of previous studies investigating relevance through the measurement of physiological signals. Results of these studies suggest that overall, physiological signals significantly differ during processing relevant content non-relevant content across individuals. Employing such an approach helped to provide valid insight into the relevance judgement process and to overcome the self-referential nature of direct and obtrusive methods, but still having an ability to focus on internal mental states of an individual. In addition, past studies investigating this phenomenon have benefited from employing knowledge from multiple disciplines, such as neuroscience, computer science, and psychology, which we seek to implement in the present study.

Relevance Feedback: The area of research interested in investigating relevance has a long theoretical background [15]. While system-oriented empirical research in this area is well established, examining the users internal processes happening during relevance judgement is relatively recent [11],[6]. Past research investigating relevance relied on filtering relevant from non-relevant information through relevance assessment and selection process from users when examining specific information presented by the search system. The selection process is therefore complex, involving a series of interactions of various components [15], which is also known as the relevance feedback cycle. The relevance feedback cycle is an indicator of perceived relevance and can be based either on explicit or/and implicit feedback [1].

Relevance & Brain Imaging: Recently, with the development of brain imaging techniques, new research begun to investigate relevance analysing neural activity in the brain. The earliest research conducted by Allegretti and colleagues in [1] using brain imaging revealed that neural signatures detectable with an electroencephalogram (EEG) along with other physiological signals could be used as a reliable indicator of relevance in real-time.

In order to investigate how does relevance happen in the brain, Moshfeghi and colleagues [11] employed functional magnetic resonance (fMRI) technique, to localise the neural activity differences in the brain while processing of relevant and non-relevant information. The study found that the differences in brain activity are the greatest in 3 regions in the frontal, parietal and temporal cortex. Later, they found that brain regions playing a crucial role during relevance judgement are the inferior parietal lobe, inferior temporal gyrus, and superior frontal gyrus and their increased activation for relevant items were related to visuospatial working memory [12].

Another research conducted by Frey and colleagues in [5] found that postrelevance judgement brain wave differences in processing relevant and irrelevant

words that persisted for one word after a relevant word (from approximately 260 to 320 ms) and two words after an irrelevant word (from approximately 500 to 530 ms). Using EEG has become a popular tool in order to study relevance and researchers attempted to employ this tool to make information retrieval process even more effective. Eugster and colleagues provided further evidence that EEG is a valid tool to study relevance and moreover found that EEG signals can be used to automatically predict relevance [4]. They found that peak significant difference between processing relevant and non-relevant words was detected in Pz channel after 450 ms, maximising at 747 ms. Later, Eugster and colleagues [3] introduced brain-relevance paradigm which enables recommendation of information without any explicit user interaction based on EEG signals evoked by users' interests toward digital content.

Allegretti and colleagues [1] used EEG in order to identify time intervals and brain activity shifting during relevance and non-relevance processing. They identified 3 time intervals: 180 - 300 ms an early process of implicit judgements of relevance (frontal areas F1; AF4) and stimuli processing. At this stage, there is no relevance judgement. Between 300 500 ms activity is shifted towards central areas C2 and CP2. During 500 800 ms, the most significant differences can be observed between the processing of relevant and non-relevant. They found that the region of interest is located in the center of the scalp - Cz, C1. In addition, Gwizdka [6] found significant differences in EEG-measured power of alpha frequency band and in EEG-detected attention levels during relevance judgement.

3 Approach

Recent findings employing brain imaging to investigate relevance have shown that human mental experiences during information retrieval process can be understood and accurately decoded using non-invasive measurements of the brain activity. Hence, recent application of neuroscientific approach has brought valid and valuable insight into better understanding of relevance. In addition, since relevance is a complex process, it is important to highlight the benefit of combining multiple data collection tools, which has become very popular in recent years. As Kelly and Belkin suggested in [8], tools such as questionnaires enable researchers to explore participant views of a task and topic familiarity, which influence relevance perception. In addition, the authors highlighted the importance of the naturalistic approach, which optimises ecological validity [8]. It is essential to design the task, which will closely model real-life user-system interaction and place relevance judgement within the context of information retrieval.

Current Work In the first study, we aim to explore aspects of cognitive relevance through the examination of the users physiological and behavioural signals. These signals will be obtained through naturalistic tasks designed for this purpose, placing cognitive relevance within the context of the information retrieval process and aiming to incorporate all its aspects, such as information need. The

study will be built on the previous literature investigating relevance through the comparison of signals associated with relevant and non-relevant information [1, 4, 3].

An in-depth understanding of cognitive relevance might not only improve the understanding of the relevance process, but it can also improve user-system interaction and result in greater search success. If the level of users cognitive abilities is low and task difficulty is high, the user might be unable to effectively interact with retrieved information and as a result, the problem solving may fail to occur [2].

Next Steps Since relevance is a complex mental phenomenon, it is essential to also consider the underlying perceptual and cognitive processes. To do so, as mentioned in Section 3, this work will aim to gather physiological and behavioural data in order to better understand participant's experience during relevance judgement tasks. Also, as a future direction of this work, we aim to go beyond cognitive relevance and investigate other relevance strata, as outlined by Saracevic [14], such as situational and affective relevance through the employment of brain imaging techniques.

4 Conclusion

Our understanding of relevance is still not complete, and thus there is a need to further investigate this key concept in IR. In this work, we aim to investigate the the concept of relevance from a neuropsychological perspective. In particular the work will focus on Saracevic's stratified model of relevance through the employment of brain imaging techniques. Further understanding of neurological properties of relevance might provide valuable insight into personalisation within information retrieval [8]. This could also lead to a significant contribution to the improvement of information systems [13]. Additionally, empirical investigation of different relevance strata might help to provide scientific evidence to validate Saracevics theoretical concept of relevance.

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