Neuroimaging Research in Social Sciences: An Overview

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Social cognitive neuroscience research refers to the interactions among analyses at the social, cognitive and neural level (Ochsner and Lieberman, 2001). Although it would appear that there are huge gaps between social science and neuroscience research, some of the interests are common to both disciplines. For example, neuroscience has a rich database on the neural correlates of emotions, stress, aggression, bonding and other social behaviours that are also the constructs of social sciences. Recently, the advancement and feasibility of several neuroimaging tools such as Electroencephalography (EEG), Functional magnetic resonance imaging (fMRI), Near-infrared spectroscopy (NIRS), etc., have led social science researchers to use theories of cognitive neuroscience for their research. Neuroimaging is a reliable and robust method that can help social sciences strengthen their existing constructs and unearth new ones.

Since the last decade, many subfields within the interface of neuroimaging and social science areas have emerged such as neuroeconomics, neuromarketing, neuroIS, neurofinance, neuropolitics, etc. that attempt to make use of neuroscience. Economics and marketing researchers started exploring neuroscience in the early twenty-first century. Other fields such as Information Systems and Finance have followed since. In this paper, we explore the evolutionary trends of social neuroscience research. We will refer to this collectively as neuroSS research. The focus of this paper is to analyze the progress of neuroSS research and compare the emerging subfields. We also study the opportunities for the emerging subfields to use different strategies to enhance their respective fields. We use two methods to explore and discover trends in the social neuroscience literature: bibliometric analysis and text mining. These methods are explained below in our context.

Bibliometrics is defined as "mathematical and statistical analyses of patterns that arise in the publication and use of documents" (Diadato 1994: viii-ix). Verbeek et al. (2002) noted that bibliometric indicators can contain adequate information to assess the performance of a field or researchers in the field. Scientific publications are the principal units of measurement in bibliometrics. The number of research publications (output) indicates the size and progress of research in a field. Similarly, we report on the number of publications over time in each area.

These indicators quantify the research output but do not explain the actual content of the research. We used text mining to learn key trends in the research. Text mining is a process of discovering new and potentially useful information from a variety of unstructured data (Delen & Crossland, 2008). Text mining can be used to make large information corpus more precise, efficient, manageable and comprehensive. It can be used as a simple application like counting the number of a particular word in a document to a more complex application such as in the biomedical field to find protein-protein interaction or protein-disease association from the literature (Ananiadou et al. 2010). Some of the other common applications of text mining are topic tracking, summarizing, clustering, categorization, concept linking and many others to extract knowledge from unstructured data. Text mining is a different approach to analyze and understand previous research.

The volume of publications on any topic in general is increasing rapidly and most papers are now available online as well. A researcher might only use a subset of the literature available, which can result in a low quality study (Delen & Crossland, 2008). There are several repositories available online that have lists of papers on an individual topic, for example, the studies published on the neuroIS can be found on neurois.org. But there is no automated system that can incorporates all the research and divide the knowledge into clusters. In this study, we applied text-mining approach that can help researchers to identify the relevant list of papers to be referenced in their studies by forming text clusters. Clustering is one of widely used applications of text mining. A cluster contains, if not complete, a sufficient list of papers related to the cluster definition.

We analyze the research published so far in the new emerging research areas using bibliometric analysis and text mining. First, we compare the pace of all neuroSS fields using bibliometric analysis. Secondly, we analyze the content of research in these areas using text mining. Five text clusters are formed that identify different patterns in the content published over time.

The two types of data used in this study were structured and unstructured data. The structured data collected were the bibliometric indicators and the unstructured data were the abstracts of the articles. The bibliometric data was collected from the four available databases on Web of Science (WoS): Web of Science Core Collection, CABI: CAB Abstracts, FSTA – the food science resource

and MEDLINE. To extract the data from various social science databases, we used a 'keyword' search method. Five keywords were used, one for each field, to collect data from five different areas: neuroeconomics, neuromarketing, neurofinance, neuropolitics and neuroIS. The search was restricted to the year 2000 - January 2014. The results of keyword searches were filtered with "articles" as the document type, which means that only journal articles made our sample data. We did not include papers published in conference proceedings because of the typically large variability in quality of publications in conference proceedings. Because the same articles can result from the two different keywords, the dataset was cleaned to remove duplicates and assigned to the relevant field. The dataset consisted of 500 papers: 421 neuroeconomics, 51 neuromarketing, 12 neuroIS, 12 neuropolitics and only 4 neurofinance papers. After cleaning the data, the bibliometric indicators retained in the dataset corresponding to each article were title, year of publication, number of citations each year (2000- Jan 2014), total citations, average citations per year and name of the publishing journal. Only some of these measures were used for analyses. The other type of information collected was unstructured in the form of abstracts. Only abstracts of the articles were used for the text mining, as we assume that abstracts contain the objective of the paper.

Text mining was completed through the following steps:

- All the abstracts collected were used as input in text mining irrespective of the field. Each abstract was considered as one document. So, the input to the text mining was a collection of 500 documents.
- The second step was to parse the text to observe the unique terms in the documents. In addition, parts of speech, entities, synonyms and punctuation were also identified. The unique terms identified during parsing were used to create a term-by-document matrix. Each identified term in the text parsing was given a weight based on the frequency of occurrences of the same word. We used maximum entropy as a text classification method to identify the important terms. The maximum entropy estimates the conditional distribution of the class label given a document.
- In the third step, filtering of the text was done so that only relevant words were used for forming clusters. To filter the text, a stop list was used that contained all the common English words and did not add value to the analysis. For example, stop list contained common words like "the", "of", "have" etc., plural terms and synonyms. All the words in the stop list were ignored for further analysis.
- Finally, the data cleaned in the previous steps was analyzed for clustering. To form clusters, the terms classified were used in expectation-maximization method. In this method, the terms within the same cluster are more expected to occur in the same documents, as compared to the terms in other clusters.

The descriptive analyses were done to understand the progress of each subfield over time. This can be seen as the number of papers published in the respective field over time. The results of analysis are presented in Figure 1. It shows that among all the areas, economics researchers were the first to explore neuroscience literature and used it in their research in 2003. The number of papers on neuroeconomics increased over the years until 2008. From 2009-2013, the growth in the research is stagnant. After economics, marketing researchers started developing neuroscience literature in 2005, but the total output has been relatively small. Until now, the neuromarketing researchers have published less than 100 papers. The finance scholars started in 2008 but do not yet have the numbers in double digits. Although researchers first used the term neuropolitics in the late 1980s and early 1990s, it has not emerged as a significant area of research for political research. Compared to all the fields, IS researchers appear to be the last to have used neuroscience theories in their research. The first major neuroIS research was published in 2010 and until now, very few papers have been published, not even twenty according to the web of science database. Comparing all, only neuroeconomics has been able to emerge as a subfield within economics and all others are still struggling to get value from the neuroscience. We also observed the major journals in each field having published neuro papers. It was discovered that most of the journals publishing neuroeconomics paper are pure neuroscience journals rather than the classical economics journals, such as *Frontiers in neuroscience, Journal of Neuroscience, Medical Hypotheses and Frontiers in Behavioral Neuroscience*. This shows the interdisciplinary nature of this field. Although some of the papers in other areas are also published in neuroscience journals, their count of publications are not yet large enough to be ranked as a major outlet for neuroSS research.

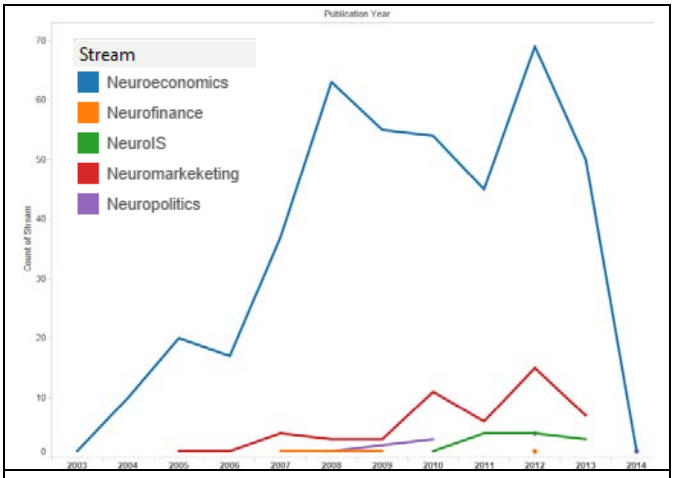

Figure 1. Number of articles published in neuroSS (2003-Jan 2014)

Using expectation maximization algorithm, five text clusters were created. Table 1 shows the top descriptive terms for each cluster and document frequency. Highly populated cluster with ID 1 comprised of 34% of the data under analysis. This cluster addresses the various social cognitive neuroscience theories applied to understand the human behaviour. Cluster 2 constitutes 22% of the total data. This cluster contains documents discussing the economics concepts such as risk-reward value, making choices or decisions and highly applied game theory. Next, cluster 3 consists of marketing research that shared 18% of the data. It contains articles that used fMRI as a primary brain-imaging tool to understand consumer behaviour. Cluster 4 is a group of 69 (14%) papers concerned about the other highly studied constructs of economics such as delayed discounting, hyperbolic discounting and impulsivity. And finally, cluster 5 was the smallest cluster with 12% of the data. It contains articles discussing about the prefrontal cortex region of the human brain that is highly used in decision-making and other social behaviours.

This is an exploratory study where we attempted to determine the trends of social neuroscience research till January 2014. The bibliometirc analysis shows that except neuroeconomics, all other streams are yet to fully develop into a sub-field within their respective disciplines. One potential reason for the growth of neuroeconomics is the alliance of the neuroscience and economics researchers. Publications of economics concepts in the neuroscience journals indicate that the constructs of economics have not only been the interest of economic researchers but also of interests to neuroscientists. This could not be possible unless researchers from both the fields share and apply common knowledge to advance their respective fields. So, this can be a lesson to all the other emerging fields to approach neuroscience experts and work together. Due to lack of training and domain expertise, it is difficult for the social science researchers to engage in neuroSS research. Experts in neuroimaging methods can help enhance the quality of research by increasing its validity. Specific conferences and workshops targeted at introducing neuroSS research methods to social science researchers have certainly increased the awareness of social science researchers, but direct collaboration between the two sides is the key to building a larger corpus of knowledge in neuroSS areas. Journals dedicated to neuroSS like *Journal of Neuroscience, Psychology, and Economics* are encouraging Neuroscience, Psychology, and Economics researchers to work together. There is no journal in IS, marketing and other fields that is similarly dedicated to the neuroscience. Although, Gmunden retreat is an annual event that tries to bring together researchers working in neuroIS, more such events and outlets will enable growth of the field. Similar strategies are highly required by the emerging neuroSS fields to encourage researchers.

Table 1. Text clusters

Cluster No.	Descriptive terms	Frequency (%)
1.	social, cognitive, neuroscience, theory, neuroeconomics, understanding, human	170, 34%
2.	risk, rewards, value, choice, game, subjects	108, 22%
3.	consumer, marketing, neuromarketing, frmi, imaging	92, 18%
4.	delay, discounting, hyperbolic, impulsivity, intertemporal, function	69, 14%
5.	prefrontal, cortex, associated, learning, ultimatum, offers	61, 12%

The clusters formed by text mining divided the data into five different groups based on the occurrences of common terms. This grouping can help researchers in finding a sufficient list of documents related to the topic of interest. For example, if a researcher wants all the relevant neuroscience research done on risk-reward value, one can find an adequate amount of related papers from cluster 2.

There are some limitations of this study. The data used might be just a subset of the neuroSS literature. The data only consisted of journal articles but in fact, the conference proceedings also contain relevant and most recent literature. Also, we tried to include all the relevant articles from the WoS database but many journals are not registered in this database. Notwithstanding all the limitations, this exploratory study provides some useful insights to the research community interested in neuroSS. We learned that several of the social neuroscience fields are not growing as fast as neuroeconomics has grown. So, there is a concern of considering different strategies to enhance this field of research. We found that fewer constructs have been studied so far using neuroimaging methods. There is a lot of scope in this area of research as many social science concepts are yet to be studied using neuroimaging methods.

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