Relationship between the nature of the Search Task Types and Query Reformulation Behaviour

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Abstract *Success of query reformulation and relevant information retrieval depends on many factors, such as users' prior knowledge, age, gender, and cognitive styles. One of the important factors that affect a user's query reformulation behaviour is that of the nature of the search tasks. Limited studies have examined the impact of the search task types on query reformulation behaviour while performing Web searches. This paper examines how the nature of the search tasks affects users' query reformulation behaviour during information searching. The paper reports empirical results from a user study in which 50 participants performed a set of three Web search tasks – exploratory, factorial and abstract. Users' interactions with search engines were logged by using a monitoring program. 872 unique search queries were classified into five query types – New, Add, Remove, Replace and Repeat. Users submitted fewer queries for the factual task, which accounted for 26%. They completed a higher number of queries (40% of the total queries) while carrying out the exploratory task. A one-way MANOVA test indicated a significant effect of search task types on users' query reformulation behaviour. In particular, the search task types influenced the manner in which users reformulated the New and Repeat queries.*

Keywords Query reformulation behaviour, information behaviour, information retrieval, search task complexity, user studies

1 Introduction

Users perform query reformulation and information searches to retrieve relevant information, satisfy their search goals and accomplish their search tasks. However, success of query reformulation and relevant information retrieval depends on many factors that govern users' information searching on the Web, such as task complexity [1], users' prior knowledge [2, 3], age [4], gender [5], information needs [6] and cognitive styles [7, 8]. One of the important factors that affect users' information searching, particularly query reformulation, and information retrieval is that of the nature of the search tasks the user is assigned to. Studies have reported that the amount of time a user spends on searching information on the Web depends on the nature of the search task; thus affecting query reformulation.

Gwizdka and Spence [9] reported that the more times searchers spent on a search task, the more Web pages they visited, and the more difficult they faced to assess and access the information. They found that low complexity tasks were characterised by shorter optimal paths (2 to 3 'clicks') and high complexity tasks by longer optimal paths (5 to 6 'clicks'). They also reported that individual differences among Web users affected the relationships between objective task complexity and subjective task difficulty.

Information searchers also tended to use more navigation tools in a general search task that required them to find a fewer pieces of information on a broad topic than they were in a specific task that required locating one specific piece of information that was known to exist on the Web [10].

This paper examines how the nature of the search tasks affects users' query reformulation behaviour during information searching. The paper reports results from a user study in which 50 research participants performed a set of three different assigned Web search tasks.

2 Related studies

Task complexity has been identified as having effects on information seeking behaviour by several researchers [e.g., 1, 9, 11-14]. Confronted with a task, the searcher perceives information needs which reflect their interpretation of information requirements, prior knowledge and ability to memorise [12]. The complexity of a task is a central feature in determining its performance and consequent information needs.

Vakkari [11] defines task complexity as a degree of *predeterminability* of task performance. Vakkari reported that the predeterminability of a task could be divided into

Proceedings of the 17th Australasian Document Computing Symposium, Dunedin, New Zealand, 5-6 December 2012.

the predeterminability of its information requirements, process, and outcome. The determinability of a task increases with the increase in the knowledge about its information requirement, process, and outcome. Bilal [15] reported that children's cognitive, physical and affective behaviours are affected by different types of search tasks while searching information on Yahooligans, a Web search engine for children. The study found that children experienced more difficulty with the research task than with the fact-based task. The study also reported that the types of search task influenced children's levels of success.

Choi [16] explored the effects of search task goals, Web search experience, work task stage and topic familiarity on the image searching process. The task goal was defined as the reason or activity that prompts the need to search. The work task stage was a user's assessment of their progress in completing a task. The study reported that most of the search interactions, such as search duration, querying, and navigating, were influenced by contextual factors.

Among the contextual factors, task goals, work task stages and searching experience were found to be the most influential. Users who performed a search for an academic task goal tended to have a longer search session and they also modified their queries frequently. Users with a lower level of search experience were found to spend more time performing searches to employ more querying and navigating tactics and to rate 'usefulness' and 'satisfaction' with search results at a lower rating than those who had a higher level of search experience.

Kim [13] argued that task difficulty depends on an individual searcher's perception, interpretation and judgment of the objective task complexity. She informed that a searcher's background, such as search experience and domain knowledge, specificity and source of information, and search process characteristics, influences the searcher's perception of task difficulty.

Kim and Allen [17] studied the impact of differences in users' cognition and search tasks on Web search activities and outcomes. Their study was designed to address how individual cognitive characteristics, such as cognitive ability, cognitive style, and problem-solving style, interact with task differences to influence Web searching behaviour and outcomes. Their study's findings indicated strong task effects on search activities and outcomes.

Different tasks were associated with different levels of search activities and outcomes. Search activities, such as the use of specific search and navigation features, time spent in searching, number of sites viewed, and number of bookmarks created, were found to be influenced by an interaction between cognitive and task variables. For completing a task, searchers spent more time for the subject search task than for the known-item search task and viewed more Web pages for the subject search task than for the known-item search task.

2.1 Search Task Classifications

Information researchers tend to categorise information search task attributes from a theoretical prospective, such as "information need" [18], "well-defined/ill-defined" [19], and "task- and fact-oriented" [20]. Borlund and Ingwersen [21] introduced the concept of "simulated work task situation", which discusses the source of information need, the environment of the situation and the problem which has to be solved; and which serves to make the test person understand the objective of the search. They argued that simulated work task situation provides with the context, which ensures "a degree of freedom" to react in relation to individual interpretation of the given situation [21].

Based on the degree of *a priori determinability* (or structuredness) of a task, that the more familiar a task performer is with the task requirement, the less complex the task is perceived, Byström and Järvelin [12] classified task complexity into five categories ranging from an automatic information processing task to a genuine decision task, as illustrated in Figure 1. In automatic information processing tasks, the process, result and types of information used can be described in advance, whereas in genuine decision tasks, none of them can be determined apriori.

Bilal [15] categorised search tasks as fact-based and research. A *fact-based* task is one that required a single, and straightforward answer. A *research* task is one that required the use of critical thinking skills to construct meaning from the relevant information found, and that had multiple facets.

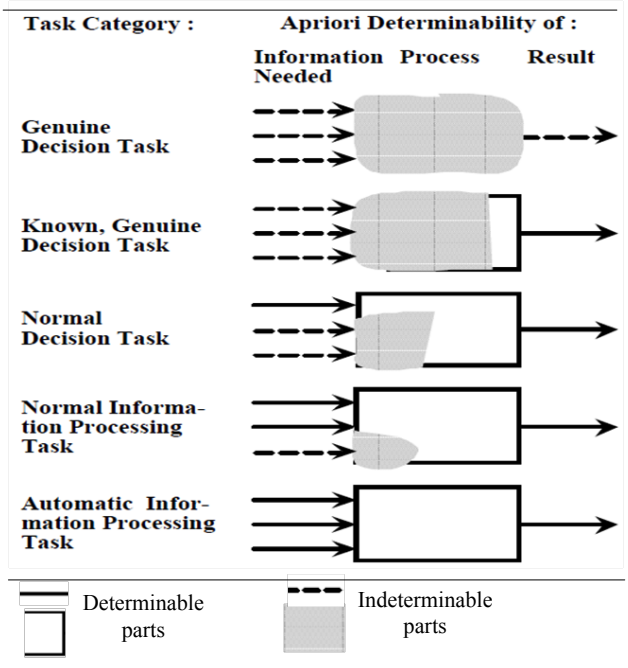


Figure 1: Task complexity categories (Byström and Järvelin, 1995)

In this research, based on Borlund and Ingwersen's [21] concept of a "simulated work task situation", three search tasks were designed to ensure that these tasks are as close as possible to real world situations (see Section 3.2).

2.2 Research Aims and Questions

While a number of studies have explored the effects of search task complexity on information seeking behaviour in general [e.g. include: 1, 9, 12-14], there is little research conducted on how search task types influence users' query reformulation behaviour.

As both search task types and query reformulations are important components of information searching, this study investigates effects of search task types on the users' query formulation behaviour. This paper also discusses query reformulation classifications adopted in the study. Thus, the research question this research addressed is:

What are the impacts of search task types on users' query reformulation behaviour?

3 Research Design

3.1 Study Participants

Sixty-five (65) responses to the study participation were received either by phone or email return. Of the 65 responses, 50 participants, comprising of students, academics and professional staff from the Queensland University of Technology, were recruited for the study. Efforts were made to include equal number of males and females across different age groups and occupations; this was done following the responses from the prospective participants prior to participation in the study.

3.2 Search Task Design

Three types of search tasks were developed: *Factual*, *Exploratory* and *Abstract*. Based on Borlund and Ingwersen's [21] concept of a "simulated work task situation" or scenario, the search tasks were designed to ensure that these tasks are as close as possible to real world situations. The simulated work task situation provides each searcher with the context, which ensures "a degree of freedom" to react in relation to his or her interpretation of the given situation [21]. This approach has been widely used by several researchers in information seeking studies [examples include: 22, 23, 24]. The search tasks designed in this study are listed below:

- Factual: *You have recently moved to Austin, Texas, The U.S., and would like to know the relevant laws passed by the Texas State government regarding child safety while travelling in vehicles. Identify three such rules.*
- Exploratory: *You, with your two friends, are planning a trek for one week in Solukhumbu in Nepal. The trekking will occur next month. You are told that tourists trekking in the place may get high-altitude illness. You decide that you should know more about the place, and the symptoms, seriousness and prevention of high-altitude sickness.*
- Abstract: *You recently heard about the Bermuda Triangle mystery, and you are curious and want to know more about it. So you want to search any relevant information (articles, images and videos) about it and what effect it has on the travellers in the region*.

The *factual* task is a fact-finding search task, such as finding three laws on child safety while travelling in vehicles. The *exploratory* task is more open-ended; there are no specific answers to such task type unlike the factual task. In an *abstract* task, the information need is abstract for which a concrete, direct solution may not exist. The abstract search task is more open-ended than the exploratory task.

3.3 Task Complexity

The search tasks were designed with different levels of difficulty and complexity. The main aim of choosing different task complexity was to suit participants with different search experience and skills. It was assumed that the *factual* task has the least complexity, in that the participants were asked to identify any three rules on child restrain while travelling in vehicles in Austin, Texas, which required them to use basic searching skills.

The *exploratory* task was more complex and required a higher level of search experience than for the factual task, in that the participants were asked to search for more information on various topics, such as place (Solukhumbu in Nepal), illness (symptoms of high-altitude illness) and safety measures (preventions of high-altitude illness).

The *abstract* task presented relatively more abstract and complex scenarios compared to the factual and exploratory tasks. The participants needed to organise and structure their search terms carefully by using a more advanced level of search skills and problem solving skills. They needed to find relevant information (that is, articles, images and videos) about the Bermuda Triangle mystery, and its effect on the travellers in the region.

Based on the observation made during the pilot study, in order to break a hierarchical level of task complexity, the exploratory task of second level complexity was issued first, followed by the exploratory and abstract tasks.

3.4 Query Reformulation Classifications

Similar to the previous works in query reformulation type [25-27], we constructed five reformulation categories based on the common and different search terms used in two successive queries: *New*, *Add*, *Remove, Replace*, and *Repeat*. Detailed definitions of each of these queries reformulation classifications with examples are illustrated in Table 1.

Type	Description	Query Examples
New	Qi and Qi+1 do not contain any common terms. All new session terms are assigned as a new query.	Q_i: "tour" Q_{i+1}: "Solukhumbu trek"
Add	Q_i is a super subset of Q_{i+1}, that is, all the terms in Qi are present in Q_{i+1} and Q_{i+1} contains more terms than Q_i.	Q_i: "Trekking Solukhumbu" Q_{i+1}: "Trekking Solukhumbu Nepal"
Replace	Q_i andQ_{i+1} contain at least one term in common and at least one different term.	Q_i: "Tour Nepal" Q_{i+1}: "Tour Solukhumbu"
Remove	Q_{i+1} is a super subset of Q_i, that is, all the terms in Q_{i+1} are present in Q_i and Q_i contains more terms than Q_{i+1}.	Q_i: "Solukhumbu tourist Nepal" Q_{i+1}: "tourist Nepal"
Repeat	Q_i and Q_{i+1} contain exactly the same terms; the order of these terms may be different.	Q_i: "trekking Solukhumbu Nepal" Q_{i+1}: "Nepal Solukhumbu trekking"

Note: Qi_{+1} is the succeeding query that follows the query Q_i in the same session.

Table 1: Classifications of query reformulations with examples

3.5 Data Collection

An invitation to participate in the study was sent via the university email. This research required a quiet environment, so an individual meeting with the prospective participant for the study participation was scheduled as per the participants' availability. First, each participant was briefed with the participant guidelines and was asked to complete a consent form.

User's demographic information was collected using a pre-search questionnaire. Each study participant was assigned with three sets of search tasks. For the Web search task, each participant was provided with a laptop with Internet access. Although the participants were never stopped while performing their search tasks, it was recommended that they spend between 10 and 15 minutes on each search task.

This study used Web search sessions to investigate each participant's interactions with the search engines. Participants' Web search interactions were captured by using a monitoring program. The output of the program is a video record that can be played and replayed at any time for transcription and analysis.

3.6 Data Analysis

The success of a research project depends on the analysis of the data to achieve something interesting and important. A standard search log file format with the following fields, similar to those of Jansen [28], was adopted (see Table 2):

User Identification: A unique number used to identify a participant
Date: The date of the interaction
The Time: The duration of the interaction
The URL: The URL of the Web site visited
Search Terms: The query terms as entered by the user

This study implemented a quantitative data analysis approach, in which the quantitative data, collected through Web search session logs, were analysed statistically, using SPSS (statistical package for social science). Basic frequency tabulations were used to inform means and standard deviation distribution of the participant demographic and Web search characteristics, such as number of queries and search terms. Advance statistical method, such as multivariate analysis of variance (MANOVA), was performed to investigate to what extent the search task types influence participants' query reformulations.

User_ID	Date	Time	URL	Search Terms
40	03/02/10	14:00	www..google.com.au	Bermuda Triangle + effects it has on travellers in the region
40	03/02/10	14:00	www..google.com.au	Bermuda Triangle + effects on travellers
40	03/02/10	14:02	www..google.com.au	hypoxia and prevention
40	03/02/10	14:03	www..google.com.au	hypoxia

Table 2: Examples of Web Search Session Logs

4 Results

4.1 Demographic

A total of 50 participants comprising students, academics and professional staff from the Queensland University of Technology participated in the study. Out of 50 participants, 26 were males, accounting for 52 % of the study sample, and 24 were females (48%). 50% of them were students, 28% staff while 22% of them were both a student and staff at the university.

More than 58% of the participant population were aged between 26 and 35 years of age. Three participants were under 20 years of age; two participants were between 46 and 55 years of age; one of the participants was over 56 years of age. The study benefited by including participants from different age groups; it was therefore not focused on a particular age group, but rather targeted users of all ages.

4.2 Time spent

Total duration of the Web search experiment performed by 50 participants was 26 hours 13 minutes and 50 seconds (rounded to 1574 minutes). Table 3 illustrates time duration for search task. As shown in the table, an average of 10 minutes and 30 seconds was spent on each search task, with a variation of approximately 4 minutes. The minimum searching time spent on a task was 3 minutes and 30 seconds; the maximum time spent was 23 minutes and 25 seconds.

Tasks	Mean	SD	Min	Max	Total	Percentage
Exploratory	00:12:47	00:04:04	00:06:05	00:23:25	10:39:51	41%
Factual	00:09:01	00:03:42	00:03:30	00:19:40	07:31:18	29%
Abstract	00:09:39	00:03:46	00:03:47	00:21:35	08:02:41	31%
All Tasks	00:10:30	00:04:10	00:03:30	00:23:25	26:13:50	100%

Table 3: Time Duration for Search Task in hh:mm:ss

On average, participants took relatively less time to complete the factual task (mean = 9 minutes) compared to the exploratory or the abstract task. We believed that this might be due to that fact that the factual task was assumed to have the least complexity. The participants were required to find only facts that existed: fact-finding tasks are easier to solve because a searcher knows what he or she needs to find. On the contrary, participants spent a longer time on the exploratory task (mean =12 minutes and 47 seconds) because the exploratory task is an open-ended task requiring more time to locate information on the topic.

In the abstract task, participants spent an average of approximately 10 minutes to complete the task. Although the abstract task was assumed to be the most difficult task, on average participants spent less time on completing it than on the exploratory task. It may be due to the fact that the abstract nature of the task provided limited direction for the participants to search on. Overall, the participants spent 41% of their search time on the exploratory task, 29% on the factual task and 31% on the abstract task.

4.3 Search queries and terms

During the scenario-based search task experiment, 50 participants submitted 872 unique search queries to complete three search tasks. A *query* is defined as string of terms submitted to a search engine per search session. As illustrated in Table 4, 350 queries were submitted for the exploratory task, 226 for the factual task and 296 for the abstract task.

Tasks	Mean	SD	Min	Max	Total	%
Exploratory	7.00	3.614	1	16	350	40%
Factual	4.52	3.570	1	19	226	26%
Abstract	5.92	3.487	1	17	296	34%
All Task	5.73	3.61	1	19	872	100%

Table 4: Frequency of search queries for each task

As illustrated in the table, participants submitted fewer queries for the factual task, which accounted for 26%; the reason being that a fact-finding task requires less searching skills. Participants completed a higher number of queries while completing the exploratory task (40% of the total queries) because it is believed that the exploratory task, being open-ended and requiring searching skills to complete, required more queries to be reformulated. In general, the average number of search queries submitted to complete a task was 5.73.

As shown in Table 5, 50 participants submitted a total of 3613 search terms to complete three search tasks each. A *term* is defined as a series of characters delimited by a white space. The average number of search terms submitted to search engines was 4.14 per query (know as *query length*). Early Web search studies, between 1997 and 2002, reported an average query length between two and three terms [29, 30]. This is something that we intend to explore in detail in future works.

On average, a participant submitted approximately 24 search terms to complete a single search task. However, there was a vast variation in the number of queries being

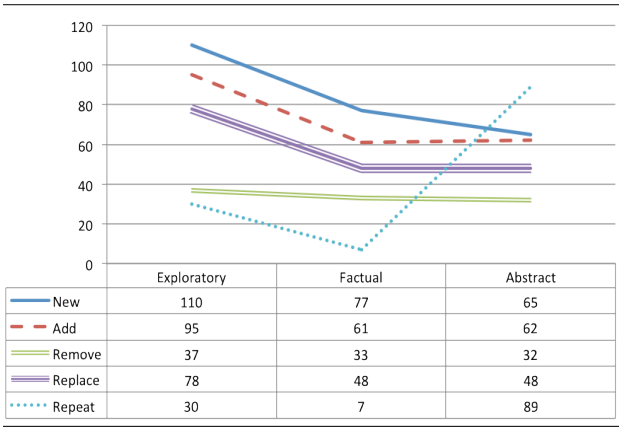
Tasks	Mean	SD	Min	Max	Total	%
Exploratory	25.46	18.10	4	78	1273	35%
Factual	26.68	26.11	4	126	1334	37%
Abstract	20.12	19.89	3	119	1006	28%
All Task	23.72	21.21	3	126	3613	100%

Table 5: Frequency of search terms for each task type

submitted (SD = 21.21), which indicated that participants varied in their query formulating.

In summary, Figure 2 presents the overview of relationships and patterns between search time, search query, and search term across search task types. Participants showed similar pattern in terms of search time spent and search query executed across the three search tasks. However, they spent a relatively longer search time and a higher number of search queries for the exploratory task than for the other two tasks; and spent a relatively shorter time and submitted a fewer queries for the factual task.

On the other hand, participants showed contradictory behaviour while submitting search terms. They submitted a relatively higher number of search terms while completing the factual task and the least number of search terms for the abstract task. This indicated that the participants seemed to submit longer queries to search facts on the Web, which may be because they were told what facts to find and they could easily use the given keywords as search terms.



	Exploratory	Factual	Abstract
New	110	77	65
Add	95	61	62
Remove	37	33	32
Replace	78	48	48
Repeat	30	7	89

Figure 2: Search time, search query and search terms by search task types

4.4 Associations between Search Task Types and Query Reformulation Behaviour

Figure 3 illustrates the overall distributions of the five types of query reformulations across the three search task types. Although all the participants completed all three sets of search tasks, the occurrence of each query types varied across three tasks. In the *exploratory* task, participants executed a higher number of *New* queries; the least was *Repeat* queries. This indicated that while performing exploratory information searching on the Web, participants preferred to search with *New* queries and least with *Repeat*.

Although the number of occurrence of each query type was relatively higher in the exploratory task, the participants seemed to display similar behaviour in the *factual* task. However, in the *abstract* task, participants tended to prefer *Repeat* queries because among the queries, they completed the highest number of *Repeat* queries. There seemed to be two possible reasons for their preference for *Repeat* queries (that is, for repeating search terms):

- We believe that the participants might have had limited possible alternative key words because of the abstract nature of the *abstract* search task. Therefore, they might have changed the order and used the same search terms again.
- Due to the abstract nature of the task, the participants might have searched the information with the same search query on different search engines, such as Yahoo, Google video or Google images.

A MANOVA test revealed a significant multivariate main effect for search task type, Wilks' $\lambda = .208$, $F(10, 286) = 8.435$, $p < .001$, partial eta squared = .228. Given the significance of the overall test, the univariate main effects were investigated. Significant effects for search task type were obtained for *New,* $F(2, 147) = 12.612$, $p < 0.01$; and *Repeat*, $F(2, 147) = 33.559$, $p < 0.01$. This indicated that the search task types (i.e., exploratory, factual and abstract tasks), influenced the way the participants reformulated *New* and *Repeat* queries.

5 Discussions and Conclusion

A one-way MANOVA test results showed that participants' *New* and *Repeat* query reformulations differed across three search tasks. The search task types influenced the manner in which the participants reformulated *New* queries and *Repeat* queries. This would have some implications for search engines designers for the design of query suggestions that are offered to users by search engines during Web searching, and information behaviour (IB) researchers who are concerned about information searchers and their query reformulation behaviours.

Search engines can identify the type of information the user is looking for by capturing the trend of the query reformulations, and then provide effective query suggestions accordingly. IB researchers can explore user–Web search interactions through analysis of users' query reformulation behaviour. Educators and researchers need to be aware that information searchers' success of retrieving relevant information depends on their query reformulation behaviour, which depends on the nature of the types of search tasks.

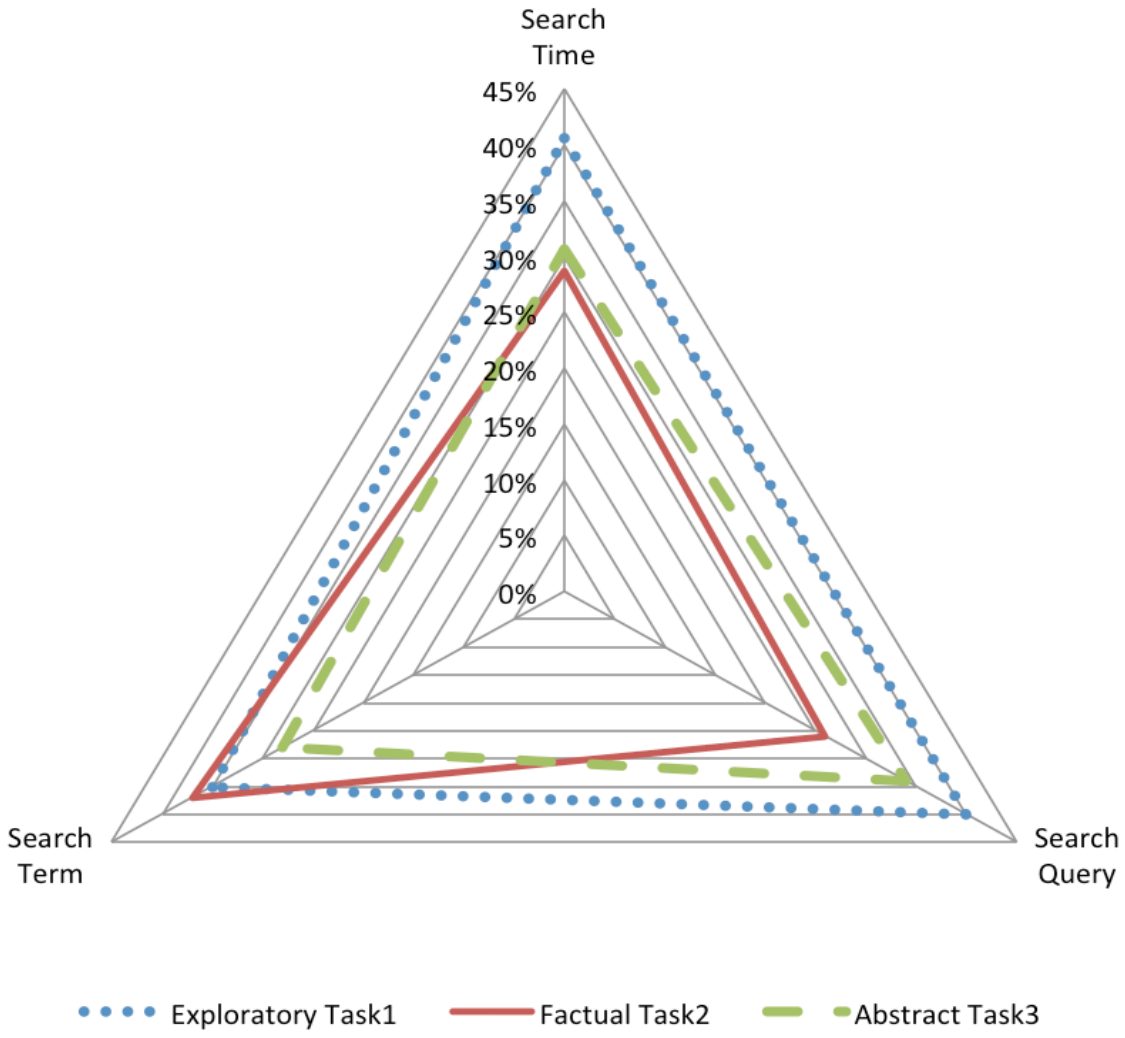


Figure 3: Distributions of query reformulation types in the three search task types

6 Limitation and Future Work

Participants were assigned with three pre-designed search tasks to complete. Although the assigned search tasks were designed as close as possible to real-world situations, and with a diverse area of topics, the subject motivation was a concern. Some participants were familiar with certain topics, while others were not. These differences in prior knowledge about the subject might have inferred the study's findings.

This research is also concerned about participants' information needs due to the fact that the search tasks were pre-designed, as these search tasks might have limited the participant's information needs. Their information needs were limited to what was required to perform the assigned search tasks, rather than being given a choice to search their own personal information need.

Future research can explore Web search behaviour in general and query reformulation in particular by asking participants to find solutions to their own identified information problems. The search tasks then can be categorised into different types based on the complexity level.

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