Exploring the Relationships Between Search Intentions and Query Reformulations

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ABSTRACT
We report on a study investigating the relationships among query reformulations and different search intentions during an information seeking session. Twenty-four participants were each asked to search for information useful for two (of four) different journalism tasks; after completing each search, the search was replayed, and participants were asked to specify what they intended to accomplish in each query segment of the search session, and whether those intentions were satisfied. Logs of the searches were analyzed to extract the queries at the start and finish of each query segment, and query reformulations were classified. Results show that: participants regularly indicated a variety of different search intentions during the course of an information seeking session; there are some differences in reformulation types following different search intentions; there are some differences in reformulation types which follow satisfied and unsatisfied intentions; and, there are differences in the frequency of intentions following reformulations which themselves follow satisfied and unsatisfied intentions. Implications for system design are discussed.

Keywords
Query reformulation, information search intentions, information seeking sessions.

INTRODUCTION
When people engage in information seeking in information retrieval systems, they often do so in information seeking *sessions*. Such sessions typically consist of several query-response cycles, in which each query may be thought of as some modification of the initial or previous query. This is a process of query *reformulation* (also known as query modification and query expansion), the process of altering a given query to improve retrieval performance (Jansen, Booth, & Spink, 2009). In fact, query reformulations comprise a large portion of web search activity (Huang & Efthimiadis, 2009) since it is unusual that users develop the single, most relevant and accurate query that can solve their information problem on their first try. Such reformulations show how users interact with retrieval systems, suggesting users' satisfaction about search results and overall retrieval performance of the system. Query reformulation is an essential element in understanding interactions in the information retrieval process (Rieh & Xie, 2006).

Fundamentally, all queries from users are closely related to their particular goals in the process of information seeking. Xie (2002) defines user intentions as goals or sub-goals that a user wants to achieve as a result of, or during the information seeking process, and which are decisive factors that determine information seeking strategies. She further identified a relatively small set of "interactive intentions", which are understood as what a searcher is attempting to accomplish at any specific stage in the information seeking session. In this model, and in the context of interaction in an information retrieval system, a query is a means of accomplishing an interactive intention. For instance, if search results are too broad or scattered, a user may reformulate the query in some way in order to accomplish the intention of getting more specific or coherent results. Or, a user unfamiliar with a system, may enter a quite general query, in order to learn about the contents or coverage of a database. Hence, how users formulate and reformulate their queries can imply what users are trying to achieve during the searching process. Thus, determining whether there are regular relationships between intentions and query reformulations, could ultimately enable information systems to predict users' search intentions based on their query reformulation behavior. This could then provide the opportunity for systems to directly support the variety of search intentions during the course of an information seeking session.

We report on a study whose aim is to investigate the relationships between query reformulations and search intentions.

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RELATED WORK

User Intentions
Most research on users' search intentions has focused on identifying, characterizing or classifying one of two

relatively high-level features: the general type of search; and, the topic of the search. Perhaps the first classification of the first type is that of Broder (2002), who proposed that web searches could be classified into three types: navigational; transactional; and informational. Others have proposed more detailed typologies of web searching, for instance, Kellar, Watters & Shepherd (2007), who proposed a scheme of Fact Finding, Information Gathering, Browsing, and Transactions. The second type of search characterization, identifying a searcher's *intent*, has been a popular research topic of late. In such work, intent is typically equated with the topic of the search, with the most typical goals being query disambiguation, and inferring search topic from very short queries. Research of both types has been concerned with intention at the level of the whole search, and not with what a person might be intending to accomplish during the course of a search session (e.g. Radlinski, Szummer & Craswell, 2010).

An important line of research has investigated what goes on during a search session. This has primarily been done within the field of library and information science, characterizing searching behaviors. Classic work in this vein includes Bates (1979) on search tactics and Ellis (1989) on information seeking patterns. Marchionini (1997) proposed a hierarchy of searching behaviors: patterns; strategies; tactics; and moves. In such research, specific types of behaviors are identified within each general category. Although each type of specific behavior may have an implied search intention, the focus has been on classifying the behaviors, rather than on understanding and classifying the intentions leading to the behaviors.

To the best of our knowledge, there has been just one example of an empirically-based classification of the different types of intentions that people engage in during information seeking, that of Xie (2002), as discussed in the introduction, and elaborated upon in Xie (2008). In this work, Xie identified a set of interactive intentions, that is, those things that the people who were studied said that they were trying to accomplish while engaging in observed behaviors, during an information seeking episode. We use a subset of Xie's interactive intentions (we call them search intentions in this paper) in the research reported here.

Classification of Query Reformulations

Prior studies have examined classification and evaluation of query reformulations or modifications. Rieh and Xie (2006) derived a facet-based query reformulation structure in the interactive information retrieval (IIR) context with three main facets (content, format, resource) and nine sub-facets. They also identified modification sequences of query reformulation as eight distinct patterns: specified, generalized, parallel, building-block, dynamic, multi-tasking, recurrent, and format, which require in-depth analysis of relationship between a pair of queries to identify a type of reformulations. Huang and Efthimiadis (2009) created taxonomy of query reformulation strategies with nine categories: word reorder; whitespace and punctuation; remove words; add words; URL stripping; stemming acronym; substring abbreviation; word substitution; and spelling correction, in order to analyze how users perform reformulations during their web searches using rule-based classifier. Liu, Gwizdka, Liu, and Belkin (2010) examined query reformulations with special attention to influences of contextual factors, task type and users' satisfaction, on query reformulation. They developed five types of reformulation according to the common terms and query length difference in two successive queries: generalization; specialization; word substitution; repeat; and new. Jansen, Booth and Spink (2009) suggested predictive models of query reformulation in web search by classifying the query reformulation patterns into six categories: new; assistance; content change; generalization; reformulation; and specialization. This structure is similar to the taxonomy of Liu et al. (2010) except the category of content change, which indicates the case when users change their information sources. Hollink, Tsikrika, and de Vries (2010) investigated the semantic types of queries by discovering the relations between queries.

METHODS

Overview of the Study

We had one major research problem; that is, is there a relationship between query reformulations and search intentions? We couched this as three, related Research Questions:

RQ1: What types of reformulations are used following any search intention?

RQ2: What types of reformulations are used when an intention is either satisfied or not satisfied?

RQ3: What are the subsequent intentions of reformulations?

To address these questions, we conducted an observational study in which we asked participants to conduct searches for information that would be useful in accomplishing different journalism tasks. Each search session was logged and recorded as video, and after each search session, participants were asked to indicate their search intention(s) during each query segment, by choosing from a list of possible intentions. They also indicated whether the intentions were satisfied or not. The search logs were analyzed to extract all queries, which were placed in a single timeline for each search session, together with the associated search intentions. The queries were classified according to our taxonomy of query reformulation types. The results of this procedure provided the data which we use to answer our research questions. Details for each aspect of the study are given below.

Query Reformulation Types

We developed a taxonomy of query reformulation based on Liu et al. (2010), displayed in Table 1. Definitions of their categories were adopted without modification, except Repeat, which we defined as any query repeated from any

of the previous queries within a single search session. Stem-Identical from the query reformulation taxonomy of Hollink et al. (2010) was added, and Spelling Correction was created after reviewing query data collected from the experiments. The queries generated by participants during their searches were then manually classified according to the rules given in the "Definition" column of Table 1.

Type	Definition	Examples
Generalization	At least one term in common in two queries; second query contains fewer terms than first query	world economic impact on global warming on Arctic region → global warming on Arctic region
Specialization	At least one term in common in two queries; second query contains more terms than first query	impact Dr. Erdmann → impact Dr.Mark Erdmann
Word Substitution	At least one term in common in two queries; second query has the same length as first query, but contains some terms not in the first query	Igor Semiletov research → igor semiletov methane
Repeat	Exactly the same term(s) repeated from any previous queries within the session	Coelacanths (1st query)→ Coelacanths (5th query)
New	No common terms in two queries	where is madagascar → coelacanths live young
Spelling Correction	The second query corrects misspelling of the previous query	methane clarites artic economic immpact → methane clarites arctic economic impact
Stem Identical	Two queries with the same morphological root	methane km → methane kilometers

Table 1. Query Reformulation Taxonomy.

Search Intentions

We used a subset of Xie's (2002) interactive intentions as the intentions from which participants were to choose. These are shown in Table 2, a reproduction of what was given to participants at the beginning of a search session, and kept by them to refer to when carrying out the task of indicating their intentions.

Identify search information

- identify something to get started - For instance, find good query terms
- Identify something more to search – Explore a topic more broadly

Learn

- Learn domain knowledge - Learn about the topic of a search
- Learn database content – Learn the type of information/resources available at a particular website – e.g., a government database

Find

- Find a known item – Searching for an item that you were familiar with in advance.
- Find specific information – Finding a predetermined piece of information.
- Find items sharing a named characteristic – Finding items with something in common.
- Find items without predefined criteria – Finding items that will be useful for a task, but which haven't been specified in advance

Keep record

- Keep record of a link - Saving a good item or an item to look at later

Access an item or set of items

- Access a specific item – Go to some item that you already know about.
- Access items with common characteristics – Go to some set of items with common characteristics.
- Access a web site/home page or similar – Relocating or going to a website

Evaluate

- Evaluate correctness of an item - Determine whether an item is factually correct
- Evaluate usefulness of an item
- Pick best item(s) from all the useful ones
- Evaluate specificity of an item – Determine whether an item is specific or general enough
- Evaluate duplication of an item – Determine whether the information in one item is the same as in another or others

Obtain

- Obtain specific information – Finding specific information to highlight or copy
- Obtain part of the item – Finding part of an item to highlight or copy
- Obtain a whole item(s) - Finding a whole item to highlight or copy

Table 2. Search Intentions.

Search Tasks

We designed four "motivating" tasks within the domain of journalism, based on the task classification proposed by Li & Belkin (2008), as modified and used by Cole,

Hendahewa, Shah & Belkin (2015). Each of the four task types was couched in terms of two different topics: coelacanths; and, methane clathrates and global warming. Table 3 shows the task types with the topic of coelacanths; the same schema was used for methane clathrates. Task types were paired into four groups, based on differences in facet values. This yielded a total of 16 possible configurations. Each participant was asked to search on one of the pairs, each with a different topic. In our data, 24 participants conducted a total of 48 search sessions, with CPE and INT having 14 searches each, and STP and REL 10 each.

Assignment 1. Copy Editing (CPE) **Your Assignment**: You are a copy editor at a newspaper and you have only 20 minutes to check the accuracy of six italicized statements in the excerpt of a piece of news story below. **Your Task**: Please find and save an authoritative page that either confirms or disconfirms each statement.
Assignment 2. Story Pitch (STP) **Your Assignment**: You are planning to pitch a science story to your editor and need to identify interesting facts about the coelacanth ("see-la-kanth"), a fish that dates from the time of dinosaurs and was thought to be extinct. **Your Task**: Find and save web pages that contain the six most interesting facts about coelacanths and/or research about their preservation.
Assignment 3. Relationships (REL) **Your Assignment**: You are writing an article about coelacanths and conservation efforts. You have found an interesting article about coelacanths but in order to develop your article you need to be able to explain the relationship between key facts you have learned. **Your Task:** In the following there are five italicized passages, find an authoritative web page that explains the relationship between two of the italicized facts.
Assignment 4. Interview Preparation (INT) **Your Assignment**: You are writing an article that profiles a scientist and their research work. You are preparing to interview Mark Erdmann, a marine biologist, about coelacanths and conservation programs. **Your Task**: Identify and save authoritative web pages for the following: Identify two (living) people who likely can provide some personal stories about Dr. Erdmann and his work. Find the three most interesting facts about Dr. Erdmann's research. Find an interesting potential impact of Dr. Erdmann's work.

Table 3. Search Tasks, Coelacanth Topic.

Procedure

Our user data was collected in a lab setting. Participants were undergraduate students from one university, recruited from undergraduate journalism courses through recruiting calls to targeted classes. Students were required to have completed at least one course in news writing. Each lab session consisted of 2 parts; in each part, participants completed a search task, an intention annotation task, and several interspersed questionnaires. They completed their entire session with a verbal exit interview. All activity except for the exit interview was conducted at a desktop computer, with search activity recorded in Firefox by a browser plugin and annotatable video of the search by Morae.[1]

Participants began with a demographic questionnaire and a tutorial video on the additional browser interface features our plugin provided. They then read the task description and answered a short questionnaire on task familiarity and anticipated task difficulty. They then had 20 minutes to complete the first search task. Afterwards, participants completed a post-search questionnaire on task difficulty and performance. They read a description of the intention annotation task and watched a video demonstrating how to conduct the task. They were also given short descriptions of each intention, as in Table 2. Intention annotation had no time limit. For the intention annotation task, participants were asked to select which intentions applied to each *query segment* (all that occurred from one query to the next) in the search session. Participants could select any number of intentions from the list, and marked whether each checked intention was satisfied. Participants could check "other" if some intention did not match the 20 provided, giving a short description and also marking whether it was satisfied. Participants repeated this process for each query segment. The same procedure was then followed for the second search task, followed by an exit interview. The entire process required about two hours per participant.

RESULTS

Because our data set is rather small (24 participants, 48 search sessions, 383 query reformulations), we present a descriptive, rather than inferential analysis of our data.

Frequency of intentions

The total number of intentions leading to query reformulations is 1,824, chosen from the 20 different intentions in Table 2. There were 1,575 satisfied intentions (86%) and 249 unsatisfied intentions (14%). The most prevalent intentions were "find specific" and "obtain specific". "identify more" was the third most popular intention. It should be noted that participants were allowed to indicate more than one intention per query segment. The median of search intentions per segment was 4.0 (range 1-16). Figure 1 shows the frequencies of intentions, satisfied and unsatisfied.

[1] https://www.techsmith.com/morae.html

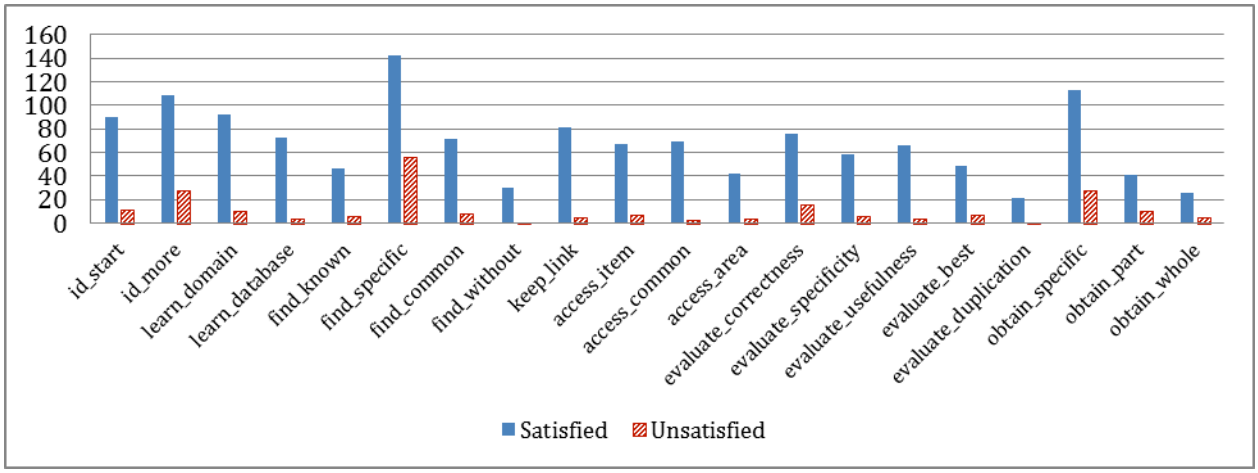

Figure 1. Total counts for each intention.

Frequency of query reformulation types (RQ1, RQ2)

There were 434 search queries, including 383 query reformulations. The first query of each search session was, of course, not classified as a reformulation. In addition, three source-seeking queries (e.g. "google scholar") were excluded for reformulation analysis. When previous intentions were satisfied, Specialization was the most frequently used reformulation, followed by Repeat, Generalization, Word Substitution, and New. When users' intentions were not satisfied, Specialization was also the most frequently used, followed by Generalization, Repeat, Word Substitution, and Spelling Correction (Figure 2).

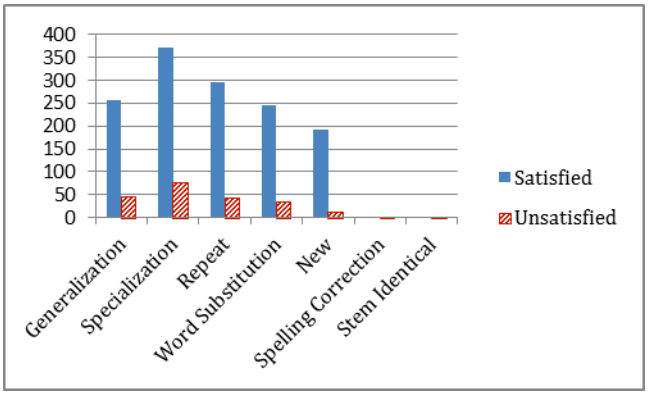

Figure 2. Frequency of satisfied and unsatisfied intentions leading to each reformulation type.

Frequency of reformulation types following each intention (RQ1, RQ2)

Query reformulation following a search intention could be indicative of the effect of satisfaction, or non-satisfaction of that intention, and of what the searcher hoped to accomplish in the next query segment. Table 4 shows the numbers of each query reformulation type that were used after each intention, when the intention was satisfied and when it was not. Each previous intention leads to different frequencies of query reformulation types. For instance, Specialization was most frequently used when the users had the search intentions including "identify start", "learn domain", "find known", "find specific", "keep link", and six others. Repeat was most frequently used when users had previous intentions including "learn database", "find common", "identify more", "find without", "access area", "evaluate duplication" and "evaluate best". Word Substitution was used when users' previous intentions were "evaluate usefulness" and "obtain whole". Although Generalization is not often used most frequently after the intentions except "evaluate correctness" and "evaluate specificity", it is particularly prevalent as the second most frequent reformulation in multiple intentions such as "find specific", "obtain specific" and "learn domain", which generated the large number of reformulations respectively.

When comparing reformulation types following a satisfied intention and an unsatisfied intention, the majority of the intentions led to the same reformulation type in both cases. Only four intentions led to different reformulations when satisfied or not satisfied: "keep link", "evaluate usefulness", "evaluate best" and "find without". For instance, when "keep link" was satisfied, Specialization was most frequently used, whereas when it was not satisfied, Repeat was most frequently used. Except for these intentions, the same type of reformulation was adopted for the next query regardless of intention success.

Frequency of reformulation types leading to intentions (RQ3)

The query reformulation type preceding a search intention could be indicative of that intention; therefore, we are interested in the relationship between reformulation type and subsequent search intention. Table 5 shows how often each reformulation type preceded each search intention. Although Specialization occurs most frequently for prior to most search intentions, the frequencies of occurrence of other reformulations vary widely for the different intentions, with all but Spelling correction and Stem identical being close to the most frequent precursors for some intentions.

Previous Intention	Satisfaction	Generalization	Specialization	Repeat	Word substitution	New	Spelling correction	Stem identical
id_start	Satisfied	18	28	21	11	12	0	0
	Unsatisfied	2	5	2	2	0	0	0
id_more	Satisfied	20	26	30	20	13	0	0
	Unsatisfied	6	8	7	4	1	2	0
learn_domain	Satisfied	20	29	19	13	11	0	0
	Unsatisfied	3	4	1	0	2	0	0
learn_database	Satisfied	14	20	20	10	9	0	0
	Unsatisfied	0	0	2	1	0	0	0
find_known	Satisfied	8	13	12	3	10	0	0
	Unsatisfied	0	2	2	2	0	0	0
find_specific	Satisfied	27	39	26	26	23	0	1
	Unsatisfied	14	17	9	11	4	0	1
find_common	Satisfied	12	17	21	15	7	0	0
	Unsatisfied	1	2	3	0	1	1	0
find_without	Satisfied	5	10	11	4	0	0	0
	Unsatisfied	0	1	0	0	0	0	0
keep_link	Satisfied	14	21	14	15	17	0	0
	Unsatisfied	1	1	2	0	1	0	0
access_item	Satisfied	11	19	13	12	12	0	0
	Unsatisfied	3	3	1	0	0	0	0
access_common	Satisfied	11	22	17	13	6	0	0
	Unsatisfied	0	2	0	0	0	0	0
access_area	Satisfied	8	8	11	10	5	0	0
	Unsatisfied	0	2	2	0	0	0	0
evaluate_ correctness	Satisfied	19	21	11	12	13	0	0
	Unsatisfied	2	6	1	4	2	0	0
evaluate_specificity	Satisfied	15	17	9	12	6	0	0
	Unsatisfied	2	2	1	1	0	0	0
evaluate_usefulness	Satisfied	13	13	13	16	11	0	0
	Unsatisfied	0	4	0	0	0	0	0
evaluate_best	Satisfied	10	9	12	11	7	0	0
	Unsatisfied	3	2	2	0	0	0	0
evaluate_duplication	Satisfied	2	4	6	6	3	0	0
	Unsatisfied	0	0	1	0	0	0	0
obtain_specific	Satisfied	23	35	17	21	17	0	0
	Unsatisfied	7	8	4	4	2	1	1
obtain_part	Satisfied	6	13	8	6	8	0	0
	Unsatisfied	0	6	2	2	0	0	0
obtain_whole	Satisfied	2	8	5	10	1	0	0
	Unsatisfied	1	1	0	3	0	0	0

Table 4. Frequency of reformulation types following search intentions.

Subsequent Intention	Generalization	Specialization	Repeat	Word substitution	New	Spelling correction	Stem identical
id_start	18	16	12	11	14	0	0
id_more	23	46	39	23	17	2	0
learn_domain	20	33	20	9	8	0	0
learn_database	18	21	15	9	13	1	0
find_known	9	11	10	8	12	0	0
find_specific	31	68	36	34	24	3	2
find_common	13	21	22	17	12	1	0
find_without	6	9	4	6	2	1	0
keep_link	15	25	12	17	112	0	0
access_item	16	22	17	11	14	0	1
access_common	13	17	17	15	6	0	0
access_area	10	13	12	5	8	0	0
evaluate_correctness	20	29	16	14	14	0	0
evaluate_specificity	15	26	13	11	5	0	0
evaluate_usefulness	17	22	16	15	10	1	0
evaluate_best	6	16	10	11	6	2	0
evaluate_duplication	4	4	7	5	3	0	0
obtain_specific	24	42	26	28	14	0	0
obtain_part	7	15	7	9	9	1	0
obtain_whole	6	8	7	8	4	0	0

Table 5. Frequency of reformulation types leading to subsequent intentions.

Previous Intention	Satisfaction	Most frequent reformulation	Subsequent intention(s)	Second most frequent reformulation	Subsequent intentions(s)
Find specific	O	Specialization	Find specific	Generalization	Find specific
	X	Specialization	Find specific	Generalization	Find specific
Obtain specific	O	Specialization	Find specific	Generalization	Obtain specific
	X	Specialization	Obtain specific	Generalization	Find specific
Identify more	O	Repeat	Identify more	Specialization	Identify more
	X	Specialization	Learn domain	Repeat	Identify more
Learn domain	O	Specialization	Find specific	Generalization	Identify more
	X	Specialization	Learn domain	Generalization	Learn domain, Learn database
Identify start	O	Specialization	Find specific	Repeat	Identify more
	X	Specialization	Find specific Obtain specific	Generalization	Identify start Find known

Table 6. Most frequent intentions, most frequent following reformulations, and most frequent subsequent intentions.

The relationship between success of previous search intention and reformulation type with subsequent search intentions (RQ3)

In this section, we consider how whether a previous search intention is satisfied or not satisfied affects the use of a particular query reformulation type, and how such reformulation type is then associated with subsequent search intentions. For display, the reformulation type which was either most or second most frequently applied to the query was obtained from when the intention was satisfied and when it was not satisfied. Table 6 shows the five most frequent search intentions with reformulation types which followed those intentions, satisfied or not, and the most frequent subsequent intention for each reformulation. The sequences of previous intention - reformulation - subsequent intention, when the first intention was satisfied, and when it was not, are of special interest. Figure 3 displays the former case, where solid (green) lines are the most frequent transitions, and dotted (purple) lines the second most frequent. Figure 4 displays the same

information when the first intention was not satisfied. Although the patterns shown in Table 6 and Figures 3 and 4 are broadly similar to one another, some differences are apparent. For instance, the intention, "identify more", when satisfied, resulted in a Repeat reformulation, followed by "identify more"; when unsatisfied, resulted in Specialization, followed by "learn domain".

Figure 3. Frequency patterns when 1st intention is satisfied: Solid green line = most frequent transition; Dotted purple line = second most frequent transition.

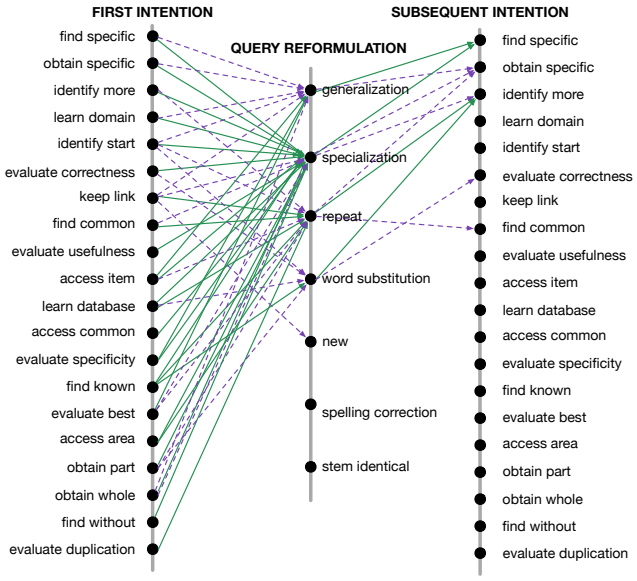

Figure 4. Frequency patterns when 1st intention is not satisfied: : Solid green line = most frequent transition; Dotted purple line = second most frequent transition Note that "new" had one transition to each of thirteen intentions; these are not displayed.

DISCUSSION AND CONCLUSIONS

With respect to the Research Questions that we posed, we have the following, rather tentative answers. For RQ1, *What types of reformulations are used following any search intention*, our results point to Specialization being the most common reformulation, following 12 of the 20 intentions, with Repeat and Generalization not far behind. However, as can be seen in Table 4, each search intention has a different pattern of frequency of associated reformulations, evident even in this small data set, which leads us to conclude that, with more data, it could be possible to at least assign probabilities of association of specific intentions with specific reformulation types.

With respect to RQ2, *What types of reformulations are used when an intention is either satisfied or not satisfied*?, our results show that there is little difference in occurrence of reformulations between satisfied and unsatisfied intentions, with differences occurring only for four of the 20 reformulation types. But because the number of unsatisfied intentions is so small, we hesitate to draw any strong conclusions with respect to this question.

For RQ3, *What are the subsequent intentions of reformulations*?, our results demonstrate that, despite the frequency of Specialization as a precursor to a search intention, each subsequent search intention has a quite different distribution of precursor reformulations. This again suggests that, with more data, it may be possible to determine probabilities of coming intentions, given a reformulation type. The analysis of intention - reformulation - intention sequences for satisfied and unsatisfied initial intentions also showed interesting differences in frequencies of subsequent intentions, associated with different precursor reformulations, which themselves differed, for several of the initial intentions.

But perhaps the most interesting result of our study is that we found that our participants had no difficulty in saying that they were attempting to satisfy a variety of intentions other than finding relevant documents, during the course of their information seeking sessions. This result, supporting Xie's (2002) results, which were obtained in a quite different context (observing people in libraries, as opposed to people doing online searching in the web), in our opinion, makes a strong case for the design of IIR systems which can differentially support these different search intentions.

The present state of affairs in IIR systems is that searchers are afforded only one or two means for accomplishing their search intentions; querying and, perhaps, following links. But the range and frequency of search intentions that we observed, combined with the frequency of use of only a few query reformulation types, suggests the need for IIR systems which offer a greatly expanded set of affordances, tailored to these different search intentions.

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