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Exploratory information searching in the enterprise: A study of user satisfaction and task performance.

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No prior research has been identified which investigates the causal factors for workplace exploratory search task performance. The impact of user, task and environmental factors on user satisfaction and task performance was investigated through a mixed methods study with 26 experienced information professionals using enterprise search in an oil and gas enterprise. Some participants found 75% of high value items, others found none with an average of 27%. No association was found between self-reported search expertise and task performance, with a tendency for many participants to overestimate their search expertise. Successful searchers may have more accurate mental models of both search systems and the information space. Organizations may not have effective exploratory search task performance feedback loops, *a lack of learning*. This may be caused by management bias towards technology not capability*, a lack of systems thinking*. Furthermore, organizations may not 'know' they 'don't know' their true level of search expertise, *a lack of knowing*. A metamodel is presented identifying the causal factors for workplace exploratory search task performance. Semi-structured qualitative interviews with search staff from the Defence, Pharmaceutical and Aerospace sectors indicates the potential transferability of the finding that organizations may not know their search expertise levels.

Introduction

The oil and gas exploration industry is a source of significant scientific and engineering activity. The industry seeks to identify and model subsurface hydrocarbon accumulations, responding to commercial opportunities requiring significant investment decisions in short periods of time (sometimes weeks). This time pressure combined with large amounts of diverse information is likely to create an environment of information overload. This makes it an ideal context in which to analyse challenging search tasks such as exploratory search (Nolan 2008). According to Marchionini (2006), search tasks can include lookup (known item) search (where there is a single correct search result or answer) and exploratory search (to investigate/learn) which may involve searching information resources for unknown quantities of information.

When searching for documents in oil and gas organizations, staff are often reliant on a small amount of textual metadata. This is because metadata is used to influence ranking of search results, may be the only way to locate and request some published digital information (as the contents may be confidential by default) or the item is physical in nature (Sawaryn *et al.* 2014, Liddell *et al.* 2003). Many project deliverables and supporting information are often stored in several places, poorly

tagged and rarely cite lists of references (Andersen 2012, Quaadgras and Beath 2011, Garbarini *et al.* 2008). Smaller levels of investment and far fewer usage statistics compared to Internet search engines, combined with information silos, permissions management and information behaviours leads to challenges in providing effective enterprise search environments (Hawking 2004).

Critically, when the 'standard model' of information seeking is discussed, researchers may not always consider that various tasks within the model may be undertaken by intermediaries (Hearst 2009, Ch. 3). Where the question is not fully formed in the Geoscientists mind, they will often search themselves and potentially make serendipitous encounters (Cleverley and Burnett 2015a). Where an information need has been clearly defined, exploratory search tasks can be handed to mediators, to search on behalf of Geoscientists (Bichteler and Ward 1989) to benefit from greater search expertise and reduce the time Geoscientists spend on non-interpretative work such as information gathering. Mediators are typically information professionals (librarians, IM consultants, Data Managers (DM) or Technical Assistants (TA)). Usage data shows for the digital library used in this study, 70% of use is by information professionals. Ehrlich and Cash (1999) conclude the expertise of professional search intermediaries can be invisible to the company in which they work. How well exploratory search tasks are performed, may influence oil and gas technical analysis and decisions. Poor search can also miss evidence of fraud (Johnson 2013) and has caused fatalities in the health sector (Savulescu and Spriggs 2002).

There is a dearth of literature on integrated models explaining the causal factors for exploratory search task performance from an organizational perspective (Vassilakaki *et al.* 2014). Models (represented by a diagram) with associations between concepts are typically rooted more closely to the real world (Case 2012) and so are of value to theoretician and practioner alike. With regards to models on information behaviour and literacy research, Wilson (2008, pg.462) comments *"many believe a position has been reached that professional education and research are irrelevant to practice".* The majority of Information Literacy (IL) research covers academic, public and Internet environments (Williams *et al.* 2014). According to Abram (2010, pg. 205), *"We need more discussion and study of the unique needs and challenges of increasing information literacy skills in the workplace".*

There is a need for research which assesses search literacy in the oil and gas enterprise. The research aim is to develop a causal metamodel for exploratory search task performance in the workplace. A number of objectives will be undertaken in order to better understand the antecedent factors for search task performance. The next section reviews the literature including factors which affect search and associated models. This is followed by the research methodology, including experimental design, limitations and method of analysis. The results are presented with discussion to help the reader better understand each finding. The paper concludes with the presentation of the theoretical metamodel, implications for theory and practice and recommendations for further research.

Literature review

This section provides a background to the areas being studied, identifying gaps to inform the research questions. In particular, identifying factors which influence user satisfaction and search task performance as well as person, technology and organization 'centric' information models.

Search user satisfaction and performance

Satisfaction is a *subjective* judgement individual's make comparing their experience to prior expectation. End user satisfaction of (and engagement with) computer systems has been measured through questionnaire instruments (O'Brien and Toms 2012, Doll and Torkzadeh 1988). Griffiths *et al.* (2007) advises caution in using user satisfaction as a measure of system performance, (pg. 150),

"We need to study the relationships held between various user and environment characteristics and satisfaction". Al-Maskari and Sanderson (2010) advocate the need to consider more than one factor at a time when researching user satisfaction. In a study of students, high levels of search satisfaction were shown for a task, despite missing key information (Wood *et al.* 1996). Despite this, many organizations continue to use user satisfaction to measure enterprise search (White 2012).

Search task performance is an *objective* assessment comparing the items located by the searcher to some form of ideal outcome. In a study of medical students (Sutcliffe *et al.* 2000) search performance was found overall to be poor, longer evaluation times and broadening/narrowing strategies led to better performance but they did not compensate for poor search term choice. Patterson *et al.* (2001) conducted an experiment using a large document collection pertaining to the Ariane 501 rocket accident, containing ten high value items. The resulting briefings from intelligence analysts that were of higher quality, were made by those that spent more time, read more documents and identified the higher value items. No measure of satisfaction was taken, so it is not known how they *felt* about their experience or how the individual or organization may have reacted to feedback. In a review of the 'search experience' variable, Moore *et al.* (2007, pg. 1537) observe *"we found that very few studies attempted to use some objective form of measuring the level of user's search performance".*

Exploratory search in the enterprise

The term 'enterprise search' typically refers to Information Retrieval (IR) technology which automatically indexes relevant enterprise content, providing a single place for staff to search without having to know where content resides (White 2012). Enterprise digital library IR systems populated from multiple locations arguably fall outside traditional definitions of enterprise search (as indexing is manual not automatic), but if approached from 'search as a process' perspective could be included.

In enterprise search most queries are single word (lookup) and often portrayed as not working well compared to Internet search engines (Andersen 2012). Many users want enterprise search engines to work like Internet search engines, but may be oblivious to the relevant content that can be missed during exploratory search tasks even using Internet search engines (Skoglund and Runeson 2009).

Unlike lookup search, exploratory search describes a range of activities from investigating and comparing to discovery and evaluation. By volume they may be responsible for 8-20% of all enterprise searches (Stenmark 2008). User interface scaffolding (Azevedo and Hadwin 2005) to guide and prompt the user (for example faceted search) have been shown to improve search performance (Fagan 2010). Interest in exploratory search user interface design is of considerable and ongoing interest (Yogev 2014, Golovchinsky *et al.* 2012, Yang and Wagner 2010, Marchionini and White 2008).

Exploratory search tasks have numerous characteristics; general, open ended, target multiple items, uncertain outcome, multi-faceted, involve query reformulation, other information behaviours and are 'not easy' (Wildemuth and Freund 2012, Kules and Capra 2008). Jiang (2014) proposes that exploratory search tasks exist in a continuum involving all these dimensions. When exploratory search tasks are investigated in the literature, there is a tendency to focus on tasks at the more complex end of the continuum (Wildemuth and Freund 2012). Simpler, 'report like' exploratory search tasks such as, *locate all the information on A for B when C*, have received less attention in the academic literature, despite these being commonplace in practice (Liddell *et al.* 2003).

Causal factors for exploratory search task satisfaction and performance

Griffiths *et al.* (2007) grouped existing literature on search user satisfaction into four themes; task, system (mixing technology and information quality), user and environmental. There has been (and continues to be), significant research on the impact of system (technology) quality on user satisfaction and search task performance (Al-Maskari and Sanderson 2010, Hildreth 2001, Frokjaer *et al.* 2000). This review has a focus on the task, user and environmental factors.

Task Factors

Bystrom and Jarvelin (1995) indicate work task complexity is a key variable in search success and user satisfaction. Enterprise information volumes are increasing rapidly which can contribute to information overload (Marcella *et al.* 2013, Hess 1999). The information overload phenomenon is a personal perception (Wilson 2001 pg. 113), *"when the flow of information associated with work tasks is greater than can be managed effectively"* and can negatively affect performance, cause anxiety and lower motivation (Bawden and Robinson 2009). With searchers making queries using an average of two words searching combined repositories containing millions of items, it is hardly surprising that many search results contain hundreds if not thousands of results (Cleverley and Burnett 2015b). Work task information overload is typically caused by a combination of information volume (and characteristics), organization design, time pressures (Crescenzi *et al.* 2013), search expertise, motivation and task type (Eppler and Mengis 2004). Bawden and Robinson (2009) suggest increasing IL may mitigate information overload. This has been taken a step further by some researchers with search task scoring rubrics to measure IL (Leichner *et al.* 2014). The effect of information overload on workplace exploratory search has received little attention in the literature.

User Factors

Individual differences such as gender (Enochsson 2005), familiarity with an IR system (Moore *et al.* 2007, Halcoussis *et al.* 2002) and personality (Heinstrom 2005) have been reported to influence information seeking behaviour. The personality trait of negative affectivity (Watson and Clark 1984) has been correlated with lower levels of search satisfaction (Woodroof and Burg 2003). Satisficers seek adequacy rather than optimality, 'good enough' (Simon 1956). Maximisers have higher levels of negative affectivity, seeking the optimal solution (Schwartz *et al.* 2002). There is little research on the impact of maximizing traits on workplace exploratory search.

Addison and Meyers (2013) divide IL into three areas; acquisition of information age skills, cultivation of habits of the mind and engagement in information-rich social practices. According to Armstrong *et al.* (2004, pg. 5), *".... Users need to respond to search results – possibly because there are too few or too many – and know when to stop searching".*

The effect of computer literacy, subject matter expertise, IR system and task familiarity on user satisfaction and search task performance has received significant interest in the literature (Smith 2014, Tang *et al.* 2013, White *et al.* 2009, Allen 1991). In a review of search experience literature, Moore *et al.* (2007) identified three methods used to collect search experience/expertise data; professional demographics, self-reporting and objective assessment. For objective assessment Moore only found measures based on frequency/time, not whether searchers had found the most relevant results.

Environmental factors

Montazemi (1988) identified several environmental factors in an organization which may influence user satisfaction of Information System (IS) usage including organizational size and design. Argyris

and Schon (1978) describe the interventionist strategies organizations make when outcomes are not as expected, single loop (operationalize actions) and double loop (question the norms). Productivity gains derived from learning curves can be significant (Argote 1999). Attitudes and behaviours toward Knowledge Management (KM) and Organizational Learning (OL) are of considerable importance to the oil and gas industry due to repeated processes (e.g. well drilling), distributed teams and an aging workforce (Grant 2013). Where an organization measures and reflects on the performance of its search technology, it is typically obtained through Information Technology (IT) capability benchmarks (White 2014, Norling 2013), user satisfaction surveys (Meza and Berndt 2014) and search analytics (Romero 2013, Dale 2013) through a search Centre of Excellence (CoE) as suggested by White (2012). These analytics based interventionist approaches are likely to favour lookup searches.

Social cognitive theory (Bandura 2001) proposes that individuals can learn from social interaction and observation, learning new behaviours without necessarily trying them. The impact of social reality on search behaviours is evidenced by cultural differences in information searching (Marcos *et al.* 2013, Kralish and Berendt 2004). Information seeking in the workplace can be a collaborative social activity (Shah *et al.* 2013). However, time and resource pressures with short work deadlines, can also make it an isolated activity with few opportunities to learn from others. Experiential self-learning (Kolb 1984) is likely to play a key part in the information search process, where searchers adapt to the results provided by the IR system. Although several studies assess searcher performance (Tabatabai and Shore 2005, Wood *et al.* 1996), they do not examine the searchers and/or organizations response when presented with knowledge of their actual search task performance.

Senge's (1990) seminal work on the learning organization painted a picture of groups of individuals continually enhancing their capabilities. Senge also argued that 'fragmentation' in order to make systems more manageable, risked losing sight of the 'big picture' and consequences of actions taken. Choo (2001, pg. 204) describes the model and concept of the 'knowing organization' citing the World Health Organization (WHO) Smallpox programme *"a triumph of management not medicine"* where a continuous flow of information (signals from the environment) and effective Information Management (IM) and Sensemaking allowed past beliefs to be unlearned and targets to be evolved.

Related information based models

People/process centric models

Wilson (1981) outlined a behavioural model where information searching was a subset of information seeking which is nested within information behaviour. Information seeking can be a dynamic, complex problem solving and learning activity, where more information is not always better (Case 2012). Today's information seeking behaviour models are typically 'person centric' (Wilson 1999, Ellis and Haugan 1997, Kuhthau 1991). These focus on the initial need, 'Anomalous State of Knowledge' (Belkin *et al.* 1982), and information source selection, including people and digital repositories (Su and Contractor 2011), through various activities (e.g. Berrypicking and information foraging behaviour (Bates 1989, Pirolli and Card 1995)) until the seeking process reaches closure.

In the workplace, Johnson and Meischke (1993) outline the antecedents to information source selection (beliefs, demographics, salience and experience). Leckie *et al.* (1996) developed a process model linking information needs to work tasks and roles. Iterative feedback loops are included in Leckie's model linking task outcome to further information seeking and/or information needs redefinition/query reformulation by the individual. Organizational feedback loops are not included,

so arguably a key situational component of search in the workplace is missing. The interconnectedness of work task, search task, cognitive actor and organizational culture on information searching has been well made (Jarvelin and Ingwersen 2004). Sweeny (2011) claimed Internet search tools have made enterprise information seekers lazy yet the supporting empirical evidence is unclear.

Technology centric models

Information quality and system (technology) quality have been part of Information System (IS) and Management Information System (MIS) success/user satisfaction causal models for over twenty years. Of particular note is the DeLone and McLean (1992) model. Subsequent research incorporated user factors into models, such as expectations (Seddon 1997), service quality (Gorla *et al.* 2010, DeLone and McLean 2002) and metadata quality (Goncalves *et al.* 2007). Technology Acceptance Models (TAM) focus on perceived usefulness and usability (Davis 1989). User based variables are considered (e.g. personality) and social influences (Venkatesh *et al.* 2003). Wixom and Todd (2005) integrated the IS System Success models (beliefs about a system) with TAM (beliefs using a system) to create a unified model for user satisfaction and acceptance, organizational factors were not considered.

Organizational centric models

In contrast to IS System Success and TAM models which see the information system as 'technology centric', Organizational Semiotics (OS) theory (Stamper 1996) posits the organization *is* the information system. Technology (automation) is nested within the formal organizational layer (roles, standards, procedures – what is written down). The formal layer is nested within the informal layer (intents, values, beliefs, norms, networks), where the way people actually work may differ from what is written down (Brown and Duguid 1991), evidenced by Choo *et al.* (2006, pg. 491) in a study of a professional legal organization "*information culture trumps information management*".

Mental models, metacognition and sense-making

Mental models are dynamic mental representations of our thought and reasoning processes where we simplify the complexity of the environment (Schoenfeld 1987, Johnson-Laird 1983). They are *"inventions of the mind that represent, organize, and restructure domain-specific knowledge"* (Seel 2001, pg. 408). These models include images, stories, relationships, lists of terms or assumptions. The mental models we create for IR systems are often flawed and unreliable (Blandford *et al.* 2007, Norman 1983) and according to some researchers play a significant role in complex search tasks (Borgman 1984). Zhang (2009) proposed a model where mental models act as mediators between individual/environmental factors and information searching behaviour.

Metacognition has been described as 'thinking about thinking' (Hacker *et al.* 1998, Flavell 1979), executive processes that control planning, monitoring and reflection, how we 'know what we know' and 'know that we don't know'. Models propose metacognitive tactics are crucial to a searchers success (Blummer and Kenton 2014, Bowler 2010, Bates 1979). The concept has also been extended to the organization (Looney and Nissen 2007). Models for 'sense-making', giving meaning to experience, exist at both the individual (Du 2014, Dervin 1998) and organizational (Weick 2005) level.

The review has led to the identification of a number of research objectives (Figure 1, Table 1) which will lead to the further understanding of exploratory search in the workplace. This includes the development of an inter-disciplinary causal metamodel for search task performance.
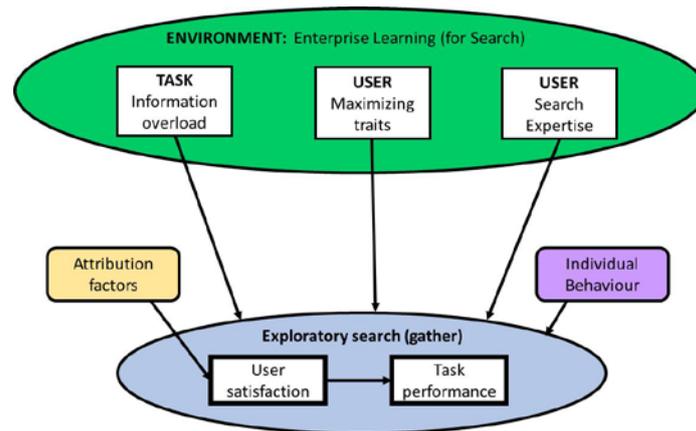
Figure 1 – The research objectives

Table 1 – Research objectives

Objective	Description
Hypothesis #1	There is a difference in user satisfaction (overload v non-overload search task)
Hypothesis #2	There is a difference in search task performance (overload v non-overload)
Hypothesis #3	There is an association between user satisfaction and task performance
Hypothesis #4	There is an association between maximizing traits and user satisfaction
Hypothesis #5	There is an association between maximizing traits and task performance
Hypothesis #6	There is an association between search expertise and user satisfaction
Hypothesis #7	There is an association between search expertise and task performance
Question #1	What are the reasons for satisfaction/dissatisfaction attribution?
Question #2	What are the information and search behaviours that lead to task success?
Question #3	What are the underlying causal mechanisms for user satisfaction?
Question #4	What are the underlying causal mechanisms for search task performance?

Methodology

A mixed methods (Creswell and Plano Clark 2011) positivist and constructivist approach was adopted for the study. This enabled the identification of statistically significant associations and identification of the reasons why, from both search participant and organizational perspectives. The triangulation (Farmer *et al.* 2006) of the mixed methods data provided a more trustworthy model for the causal factors that lead to exploratory search task performance, than using a single method.

Data sampling and collection

A large (100,000 staff operating in 90 countries) oil and gas operator was the unit of analysis for the study. The staff and organization were anonymized to prevent recognition by competitors, stakeholders and peers. A sampling frame list was drawn up of staff based in North America, Europe and Australia. This consisted of librarians, IM consultants, DM and TA's. The sampling frame contained all librarians and IM consultants supporting the oil and gas exploration department, which in part determined the sample size. The DM and TA's co-located with geoscience teams were more numerous and had wider ranging roles including structured data management.

The sampling frame (Evans and Rooney 2013, Ch. 6) was divided into two; firstly Librarians, IM Consultants and Corporate DM's, secondly co-located DM's and TA's. The latter group do not perform unstructured information searches as frequently as the former group (supported by search

log data), so the lists were sampled in an approximate 2:1 ratio choosing two Librarians and IM Consultants for every one randomly sampled member from the DM and TA group (size=62). At sample number 24 only one member was left from the Library/IM Consultant group, so they were chosen along with one from the DM/TA group. This gave a total sample size of 26 which is comparable to similar studies (Thomas and Hawking 2006, Johnson et al. 2003). This provided a better representation of overall 'search expertise' supporting the exploration department, than random sampling methods.

Each selected staff member was contacted via email to explain the nature and purpose of the research project, seek their participation in the research, and assure the confidentiality of their data and personal anonymity. Each participant was given a unique identifier, the first participant being [P1], and the last [P26]. No participant was aware of the research questions or hypotheses being tested. Every participant contacted by the researcher agreed to take part in the research. A breakdown of the sample by category is shown in figure 2, illustrating gender-role differences which would be tested.
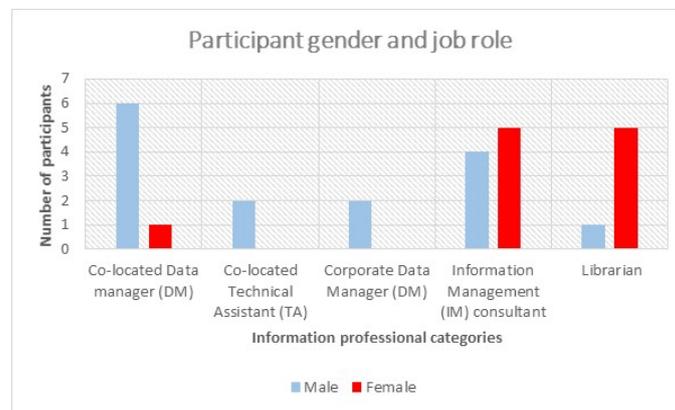
Figure 2 – Breakdown of study participants (n=26)

Research design - Experiment

The research design captured data on individual factors (age, native language, gender) through a questionnaire to ascertain if they had an effect on results. Age data was collected by category (<30, 30-40, 40-50, >50 years). Familiarity of the IR system was defined by how many searches each participant had made in the library during 2014, avoiding self-reporting which may overestimate usage (Junco 2013, Roy and Christenfeld 2008). In total 6,671 search queries were made by participants in the sample during 2014. The user factors (familiarity with the oil and gas search task, level of subject matter expertise and spatial cognitive ability) were somewhat contained through the sampling and research design. Variability of conditions was mitigated through the tasks being performed individually by participants supporting oil and gas exploration during the same month in the same organization using the same tool with the same set of instructions.

The enterprise digital library used in the study contains only metadata with all participants seeing the same search results (i.e. no permission-based security trimming was used).

Task – provoking information overload

A suitable work task was identified based on interviews with geoscientists and historical search log data. Search tasks involving the topics of 'Gravity' and 'Magnetics' (Kearey *et al.* 2002) were chosen as these would make the task relevant and multi-faceted. In a real situation, these search tasks would form part of a much larger set of search tasks required to address the work task.

Additionally, the topics are very specific, narrow and self-contained, unlikely to provoke a search for synonyms which is important in order to isolate search expertise from domain expertise. Two countries were identified in the company library system that, using the existing content in the system, would produce a large (>300) amount of search results for queries around gravity and magnetics (Peru) and a smaller (<100) amount of results (Cyprus) which would act as a control. The work task was presented to the participants in the instructions:

> **Work task: Upcoming government petroleum license rounds require decisions on which blocks to bid on. In order to make the decision, it is necessary to gain an understanding of the regional subsurface plays in a short space of time.**

- **Search Task1 – Gather recent gravity, magnetics reports for Peru**
- **Search Task 2 – Gather recent gravity, magnetics reports for Cyprus**

Although the search task was relatively specific/directed, it was felt that it would stimulate certain exploratory search behaviour due to the following factors: it was multi-faceted; targets multiple items; involves decision choices on relevancy; and has uncertainty of outcome as the quantity of candidate items present in the IR system are not known.

User satisfaction

A questionnaire was undertaken by participants after completing the search task. Participants were asked to complete their level of satisfaction for each task using a 5-point Likert item (Colman *et al.* 1997) in the format (1 = *very dissatisfied*, 5 = *very satisfied*). The findings generated from these data were used to address Hypothesis #1, #3, #4, #6 and Question #1 and #3.

User self-reported search expertise

Using 5-point Likert items in the questionnaire, participants assessed their own search expertise (1 = *very poor*, 5 = *very good*). This would be used in Hypothesis #6 and #7 and Question #2 and #4.

User personality maximizing traits

Participants used a nine question 7-point Likert scale (1 = *disagree completely*, 7 = *agree completely*) to indicate their maximizing personality traits, collecting data for Hypothesis #4, #5 and Question #1-4. The nine questions were a derivative of the maximizing psychometric questionnaire (Schwartz *et al.* 2002), for example, '*No matter what I do, I always have the highest standards for myself*'.

Search task performance

Four records (Table 2) were added to the library for each task with a published date of November 2014 (library search ranking is not by date), testing basic search syntax knowledge and use of wildcards.

Table 2: Title metadata of the high value items added where xx=country name (Peru or Cyprus)

No.	Title	Search syntax tested
N1	xx Gravity Interpretation Report	Use of subject terms, noticing recent date
N2	xx Magnetic Interpretation Report	Use of subject terms, noticing recent date
N3	xx GravMag Interpretation Report	Use of wildcards after terms, noticing recent date
N4	xx Aeromagnetic Interpretation	Use of wildcards before terms, noting recent date

These items would appear in search results with exactly the same 'look and feel' as other records in the system.

The term *high value items* is used to refer to the four records added by the researcher for each task, which are the only items with a 'very recent' 2014 published date (most relevant reports were much older). In this study *search task performance* is based on how many of these high value items were found by the participant, collecting data for Hypotheses #1-7 and Questions #2 and #4.

Experiment format

Through random assignment, half of the participants performed the information overload task (Peru) as the first task and the other half performed the information overload task as the second task. This was designed to reduce the effects of task order bias and allow a test of independence to be performed to identify if task order influenced responses.

Instructions were emailed to participants immediately before the experiment started, with the constraints. Although it created an artificial situation, the decision to constrain relevancy judgements to just metadata (e.g. title and date) helped isolate generic search expertise from subject matter domain knowledge. Otherwise it would have been possible for a searcher with low expertise, who may have some subject matter (terminology) knowledge, to perform better than a searcher with higher levels of search expertise and lower subject matter knowledge. The list of constraints used are shown in Table 3.

Table 3 – Instructions and constraints sent to participants

No.	Constraint	Reason	Accepted limitation
C1	Only use the global library catalogue	Easier comparison of search skills & literacy	Staff may use multiple sources (Li and Belkin 2010)
C2	Only use the free text library search window - and the basket and export to Excel search functions.	Control spatial cognitive ability and the influence of how well people know the functionality of the library system.	Analysis of one years of search logs (280K queries) indicate 87.7% of usage is from the text search-window. However, facets are used/of value (Cleverley and Burnett 2015b).
C3	Relevancy to be decided on surrogate metadata only (title and date) no opening of documents.	The study did not want to test subject matter knowledge (topic familiarity).	Created an artificial situation as typically searchers would open some documents to assess relevance.
C4	Take a maximum of ten minutes per task	Create sense of time pressure.	Some exploratory tasks may take longer than 10 minutes.
C5	Identify (up to) the ten most relevant items	Cannot read all items choices have to be made.	Artificial number.

The researcher avoided contact with participants to minimize observer expectancy effects. However, the researcher was able to view the search log in real time during the task (which confirmed compliance with instructions). The participants were not aware of this, thus mitigating any observer effects. A limitation of this approach was that the researcher was not able to observe cognitive and behavioural nuances not captured by the search log data. Such 'think aloud' protocols (Beresi *et al.* 2010) can be useful to help examine the thought processes of searchers, but have their own drawbacks, *"It's hard to talk and think of what I'm trying to say. Very difficult"* (Tabatabai and Shore 2005, pg. 236). To reduce the use of too many artificial contexts, this method was not used.

The participants were told they could spend no more than ten minutes per task, based on evidence that most topically coherent simple exploratory search sessions do not last longer (Hassan *et al.*

2014). The ten minute limit enabled a consistent comparison between participants and created an environment of time pressure. The participants were asked to email the items they had identified from task #1 and their level of satisfaction to the researcher before starting task #2. This was designed to eliminate any effects of task #2 satisfaction perceptions subconsciously influencing the level of satisfaction for task #1. For each task the participant was also asked to send, via email, the most relevant documents found (up to ten per task) forcing relevancy choices to be made.

Completion of the two search tasks (20mins) and subsequent questionnaire and interview (25mins) took the total time to 45mins. Testing with a pilot group indicated this time commitment was acceptable as an upper limit. It was therefore decided that only two search tasks would be used otherwise a risk of non-participation bias may be introduced. The literature supports using a small number of search tasks (Tabatabai and Shore 2005, Cox and Fisher 2004).

On completion of task #2 each participant was sent (via email) a questionnaire to complete with instructions to send back to the researcher.

Identifying causal factors

Participant interviews

After completing the search task and questionnaire, semi-structured individual participant interviews based on the critical incident technique (Flanagan 1954) were conducted to gain deeper insights on why certain activities had been undertaken, addressing Questions #1-4. In an exploratory search task, the searcher would typically not know the 'optimal' set of results for the given task and searchable information. During the interview, the researcher created an objective feedback loop and shared (in a positive tone) how many of the high value items the participant had located and then asked the participant how they felt after being presented with this new knowledge.

Organizational interviews

Semi-structured interviews took place with the General Manager for Exploration IM and the Search CoE Manager in the study organization. The purpose was to feedback task performance and understand the research findings in the wider organizational learning context.

Transferability

Themes identified in the hypotheses and questions were discussed in semi-structured telephone conversations with Search/KM managers in six purposefully sampled (Coyne 1997) organizations (treated anonymously and labelled [O1] to [O6]) which employ scientists and engineers. These included the industry sectors of aerospace, pharmaceuticals, defence, professional societies, IT and oil and gas, to ascertain the potential transferability of findings.

Analysis

The analysis was structured according to the quantitative and qualitative methods used, as well as how the findings from both methods were integrated and triangulated.

Statistical inference tests

The Kruskal-Wallis test was used to test for statistical differences by age category. The Mann-Whitney U test was used to test results by gender and native language (English, non-English). The Wilcoxon Signed Rank test was used to test effects of task order (Clason and Dormody 1994).

Association analysis is useful for identifying strengths of relationships and highlighting areas for further research. For Hypotheses #1-2, the Wilcoxon Signed Rank test was used to identify any statistically significant associations between tasks for user satisfaction and number of high value

items found. For Hypotheses #3-7, where associations between variables are undertaken on Likert Items or scales (ordinal non-parametric data), the Spearman Rank Correlation Coefficient was used (McDonald 2014, Salkind 2010). Scatter plots were also created to look at possible relationships. A 5% significance level, commonly adopted in social science, was used for all statistical tests. With n = 26, a two tailed Spearman's coefficient of $\rho \geq 0.39$ is deemed to be statistically significant (Weathington *et al.* 2012).

Thematic analysis

The search log data captured the queries used by each participant during the experiment. This data was analysed to generate themes (e.g. broadening, narrowing, parallel search strategies). A baseline query level was established as 'broad' (a country and gravity or magnetics) and then all queries were classified 'narrow' or 'broad' relative to this. Themes were also mapped from the qualitative survey data and interviews using an approach based on grounded theory (Strauss and Corbin 1998).

Triangulation

As a number of hypotheses were tested, there is a possibility of multiple testing problem effects. Bonferroni corrections have not been applied because simultaneous tests (e.g. ANOVA multiple comparisons), have not been performed for this exploratory study. The qualitative data was analysed to support any findings where an association was discovered. Themes which emerged from the search log data, questionnaires and interviews were analysed to look for areas of agreement or dissonance.

Results

The results are organised by research objective. A discussion of the findings is also presented in this section, highlighting the relationships between this work and prior research.

Tests for independence

Kruskal-Wallis and Mann-Whitney U tests for the effects of age and (gender and native language) respectively, indicated they were not statistically significant. The Wilcoxon signed-rank test indicated the effect of task order was not statistically significant. No association was found between IR System familiarity and task performance for task #1, with a statistically significant ($p<0.05$) association for task #2. This may indicate that the influence of IR system familiarity on search task performance diminishes in information overload situations. Participants confirmed task #1 provided information overload *"Initial data overload"* [P10], compared to task #2 "*easier to make choices with limited results*" [P3].
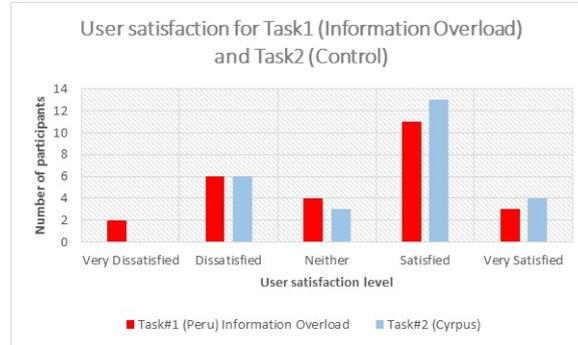
Hypotheses

A summary of the high value items found and user satisfaction for task #1 and 2 is shown in Table 4.

Table 4 – Task performance and user satisfaction for task#1 and task#2

Task	% high value items found	AVE NO. high value items	STD high value items found	Satisfied or Very satisfied
Task#1	18%	0.73	0.81	14 (54%)
Task#2	36%	1.42	1.11	17 (65%)

Hypothesis #1 – There is a difference in user satisfaction between task#1-2

The Wilcoxon signed-rank test for user satisfaction (Figure 3) between task#1 and task#2 is not statistically significant (P>0.05). For 54% of the participants, user satisfaction levels did not change from task#1 to task #2. It is possible some participants satisficed when providing this data.

Figure 3 – User satisfaction levels for the two tasks

Hypothesis #2 – There is a difference in task performance between task#1-2

The Wilcoxon signed-rank test for the number of key items found (Figure 4, Table 4) between task #1 and task#2 indicates differences are statistically significant (P<0.05), decreasing from task #2 to task #1. The results indicate information overload impacts search task performance.
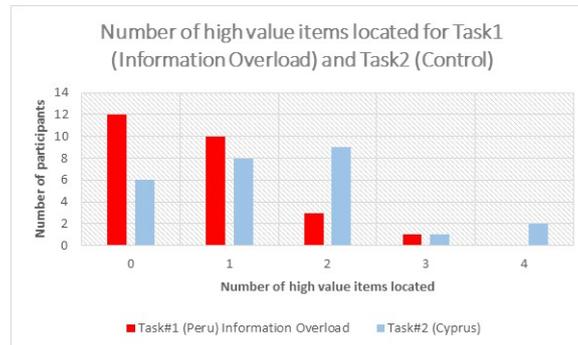
Figure 4 – Number of high value items located for the two tasks

Hypothesis #3 – There is an association between user satisfaction and task performance

For task#1 information overload (Table 5) no significant association exists. For task#2 (ρ=0.41) a statistically significant association exists, performance increasing with satisfaction. The data suggests user satisfaction may be a poor predictor of search task success in information overload environments.

Table 5 – Associations between factors (Spearman ρ)

Factors Correlated	Task#1	Task#2
[H3] User satisfaction to TASK PERFORMANCE	-0.25	0.41
[H4] User satisfaction to maximizing personality traits	0.25	-0.07
- High Standards	0.03	-0.14
- Choice difficulty	0.22	0.05
- Decision difficulty	0.02	-0.22
[H5] TASK PERFORMANCE to maximizing personality traits	0.1	-0.19
- High Standards	-0.05	-0.31

- Choice difficulty	0.11	-0.22
- Decision difficulty	0.06	0.13
[H6] Self-reported search EXPERTISE to user satisfaction	-0.03	0.05
[H7] Self-reported search EXPERTISE to TASK PERFORMANCE	-0.33	0.05
TASK PERFORMANCE to user satisfaction Δ (Task#1- Task#2)	0.69	

*A 5% statistical significance requires ρ ≥ 0.39

The strongest association discovered (ρ=0.69) was between the inter task *difference* in user satisfaction (task#2-task#1) to combined high value items found (task#1 & task#2) (Figure 5).
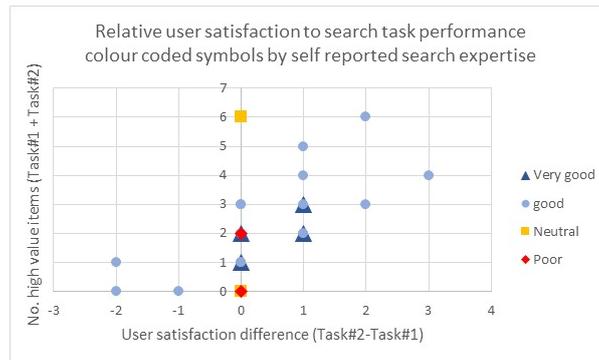
Figure 5 - Relationship between satisfaction differences, overall performance and reported expertise

Most of the more successful participants were less satisfied with task#1 (information overload). Participants having more accurate mental models may have both perceived and understood the impact of information overload on uncertainty of outcome.

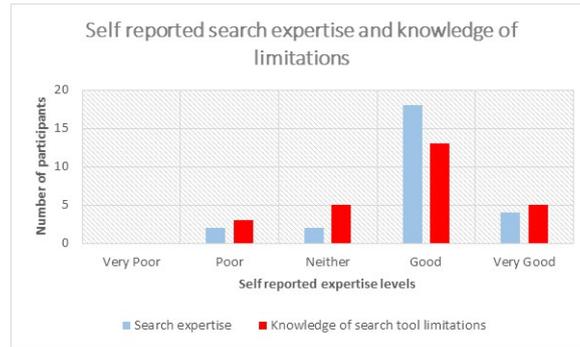## Hypothesis #4 – There is an association between maximizing traits and user satisfaction

There was no significant association in the sample between maximizing personality traits and user satisfaction in the task scenarios. Contrary to previous research (Woodroof and Burg 2003), no link was found between personality traits and user satisfaction. It is possible that the maximizing questionnaire is a poor fit for the modern workplace. Participants struggled with several questions relating to gift shopping and switching television channels (some participants did not watch television very often). Another possible explanation is that individuals adopt one type of behaviour (e.g. maximizing) in everyday life and another in the workplace (e.g. satisficing). As put by one participant *"I consider myself a maximizer, but in the workplace I don't have time to be a maximizer"* [P18].

Hypothesis #5 – There is an association between maximizing traits and task performance

There was no significant association between maximizing personality traits and search task performance.

Hypothesis #6 – There is an association between search expertise and user satisfaction

From questionnaire data, 85% of participants rated their search expertise as good or very good (Figure 6), with 73% using Internet search daily. This data may have been biased by the experiment experience and could have differed had they completed this section before the experiment. However, the two participants that indicated their level of search expertise was 'poor' in the questionnaire, stated this in emails to the researcher at the time of participation (so was not changed by the experiment). No significant association was found between self-reported search expertise and user satisfaction.

Figure 6 – Self-reported levels of search expertise and knowledge of search tool limitations

Hypothesis #7 – There is an association between search expertise and task performance

No significant association was found between self-reported search expertise and search task performance, as illustrated in Figure 5. It is possible the Likert item was not sophisticated enough. Alternatively, searchers may overestimate (in a few cases underestimate) their own competence.

Questions

Question #1 – What criteria was used for satisfaction and dissatisfaction attribution?

The criteria used for satisfaction/dissatisfaction were identified. For task#1 there was a perception of lots of content (enough for some to be satisfied). Not enough time and a belief that there must be better items yet to be found made participants feel dissatisfied, which may be linked to expectations.

For task#2 a confidence (uncertainty reduction) theme emerged, caused by an ability to perform more searches as there were fewer results, participants felt it easier to make decision choices from the search results (Table 6).

Table 6 – Reasons for satisfaction and dissatisfaction from questionnaires and interviews

	Task #1 Peru (Info. Overload)	Task #2 Cyprus
Satisfied	Emotion (Task enjoyment)	
	Information quality - Many results	
		Confidence (Uncertainty reduction)
	Information quality – (Recent items, topically relevant, easy to understand)	
	System Usability - Quick and easy	
Dissatisfied	Emotion (Task frustration)	
	Belief, suspicion more or better items	
		Information quality - Metadata not clear
	Not enough time to look properly	
	Information quality - No recent results	

Participants that indicated 'good enough' or 'found the most relevant' as a reason for stopping their search, were generally more satisfied than those that indicated 'out of time' or 'could not think of any other query terms'. Information quality was given as a reason for dissatisfaction, "*I was intrigued by Bob Regional Study*" [P21].

The themes identified from the research study support the generalizability of the existing literature (O'Brien and Toms 2012, Doll and Torkzadeh 1988). The nature of the search task may also be a factor.

Question #2 – What information behaviours (IB) led to higher levels of task performance?

The search log was analysed to identify behavioural tactics indicative of higher levels of search task performance. In general, the participants exhibited quite diverse search tactics perhaps highlighting the lack of any standard search protocols.

Around half of participants started with a broad search query and half with a narrow search query (compared to a baseline of a country and the topic of either gravity or magnetics), although there was no relationship to actual search task performance.

A participant with 'poor' self-reported search expertise [P24] used term juxtaposition, executing both the query 'cyprus gravity' and 'gravity cyprus' (a space being an AND operator). Changing the order of terms makes no difference to search result recall, but may influence result ranking. During the interview the participant admitted they were not sure what a 'space' meant in their search query.

Two participants [P8 and P26] with self-reported expertise levels of 'good' made the query 'gravity magnetics for Peru'. This may indicate a lack of understanding when searching limited metadata, as items not explicitly containing the word 'for' will not necessarily be returned in results unless the search engine is configured to drop common 'stop' words (Fox 1989). Some library and enterprise search engine deployments (including the one used in this study) are not configured in this way.

Several participants exhibited 'conceptual drifting', including the terms 'Mediterranean' [P4, P1] and 'Bid round' [P2] in their search queries. Only one participant [P23] used exact phrase ("") quotes in Task#1. Although this did not help, it was the right tactic for an information overload task.

The behavioural praxes and traits that led to higher levels of search task performance are shown in Table 7. Two of the participants that performed relatively poorly appeared to have not absorbed the instructions thoroughly leading to outlier query construction [B1]. It was observed that 38% of participants [P4, P7, P8, P10, P11, P15, P16, P19, P24 and P26] did not realize the criticality of only using the plural form [B2] when searching. Queries on 'magnetics' did not yield items mentioning only 'magnetic'. Well known public scholarly search engines also behave with similar characteristics.

Table 7 – Behavioural praxes and traits that led to success

No.	Name	Description	Tactics*
B1	Absorbing instructions	Not missing critical task information	Think, Notice
B2	Understanding plurals	Impact of plurals/lemmas on searching	Identify
B3	Query Discipline	Methodical query behaviour	Regulate
B4	Avoiding Boolean OR queries	Risk of incorrect formulation if used without brackets; little value in overload contexts	Identify
B5	Query formulation (use of Wildcards)	It is not just using wildcards, but using them effectively with appropriate truncation	Identify
B6	Brute force persistence	Effort: Many queries, deploying	Regulate
B7	Creativity	Lateral, divergent thinking	Meditate, Jolt
B8	Effective results synthesis	Diligence inspecting and picking relevant items in results lists, sorting, trimming.	Meditate, Identify
B9	Adaptation	Adapting to the results returned, recognizing unproductive queries.	Catch, Break, Skip

*Mapped to (Blummer and Kenton 2014, Bates 1979)

As part of the iterative process of enquiry, analysis of search log data from 2013/2014 confirmed the existence of many exploratory search tasks undertaken in the organization by Geoscientists (outside the study sample) where only the plural form of a query was made. Items that were missed were subsequently shown to the original searcher, confirming that relevant (and useful) information that had been present at the time of the original search task had been missed. This hints at the transferability of [B2] beyond the population of mediators, to include Geoscientists.

Word stemming techniques applied to search query terms can cater for the plurals issue but can decrease the precision of search results. The use of thesauri and lemmatization by search engines for query expansion can improve result recall but are dependent on subject matter domain coverage and quality. Publically available machine learning techniques used by some Internet search engines (Mikolov *et al.* 2013) can automatically identify statistically likely synonymous words or phrases (including plurals). However, these techniques do not appear to be used in many enterprise search tools, supporting observations from practioners (Andersen 2012).

Some participants missed high value items due to inconsistent strategies [B3] between the two tasks. For example [P19] missed searching explicitly for gravity information for Peru by accident. Where the Boolean query operator 'OR 'was used [B4] outcomes were generally poor either because it returned far too many results [P9 and P14] or were formed incorrectly with missing brackets [P4, P17, P19 and P24]. This was a major issue for one participant [P11] who only made a single query and failed to recognize (from the topically incoherent search results) that it was formed incorrectly.

The librarians in the sample constructed the most sophisticated queries e.g. 'peru (gravity OR magnetic*)', but were often outperformed by those that did not. Wildcards [B5] were used by those who found many key items and those who found none. The critical factor is probably not whether wildcards are used, but *how* they are used. Whilst the use of the query (where an asterisk is a wildcard) 'magnetic*' and 'gravity*' would pick up plurals and other variants as used by [P6, P9, P14, P25] only [P18] used the truncated syntax 'mag*' and 'grav*' finding the item [N3] 'gravmag'. No participant used a wildcard before or intra- term so failed to find the high value item [N4] 'aeromagnetic'. One participant [P25] with 'good' self-reported search expertise and used Internet search every day, made a wildcard query 'reports*' which reveals some misunderstandings on how wildcards work.

The use of many queries and paging to see more results [B6], rather than one or two queries tended to lead to better outcomes, a tactic termed 'brute force' persistence, broadly supporting existing research findings on search behaviour (Sutcliffe *et al.* 2000). There was evidence of creativity [B7], with one participant [P2] making an informed guess that Cyprus was unusual (from an oil and gas perspective) so would not have many items. They made a query using just the country name and exported all results, sorted on date and discovered all high value items - the strategy was effective.

Some participants formulated the right queries, but failed to identify the high value items in their results list. This was followed up in the interviews, however it is still not clear why the items were missed as participants could not offer any specific explanation. A search results handling [B8] strategy adopted by some of the more successful participants involved collecting items they thought most relevant from various results pages, adding to their basket as they went along (examples of 'Berry picking' and information foraging (Bates 1989, Pirolli and Card 1995)). Decision strategies (Payne *et al.* 1993) appeared to influence the items chosen (trimming) from the basket at the end of

the task. Participants displayed evidence of compensatory and non-compensatory methods (applying cut offs).

Analysis of the search queries made intra-task and inter-task identify participants that were adapting [B9] (learning) from the results returned for their queries and the differing information volumes provided by each task. This can be observed in the number of search queries used and how they evolved. Some participants did not seem to adapt which on occasion led to less successful outcomes.

Although some participants that did comparatively well used up the full time allocation, one participant [P18] completed both tasks in 7 minutes (as opposed to 20 min), finding 75% of high value items using just two unique queries per task. This indicates that, with the right level of knowledge, it is possible to expend little effort and still deliver high quality outcomes.

Question #3: What underlying mechanisms cause differences in user satisfaction?

Three themes were identified for user satisfaction differences: Enough time/control, enterprise information governance and mental models (expectations, comfort levels, background of individual).

For task#1 simulating information overload, there was often a lack of comfort due to loss of control through time constraints *"lots of results not enough time"* [P10], *"too many results"* [P17].

Information quality concerns, for example "*I felt the metadata was not clear enough*" [P15] affected satisfaction levels, likely caused by a lack of rigorous governance on information publishing processes.

Some participants held beliefs there *"must be more documents*" [P1], which led to dissatisfaction. Conversely, participants felt satisfied because there were results "*I had FOUND something*". Comfort has already been identified as an attributing factor for satisfaction mainly for task#2. Here, the participant was able to demonstrate their search skill, without the disruption of information overload, backing themselves to have found the most relevant items, evidenced by; "*easier to make choices with limited results*" [P3], *"search results were smaller so the likelihood of decent information retrieval was better."* [P9] and "*Overall I was more satisfied with the results I got for Cyprus as I used more targeted searches (mainly forced by the fact that there were very few results in my first search query)."* [P2].

For task#2, the comments made by [P22], *"found all possible results currently available"* and [P7] *"A few searches obviously exhausted the limited data available"*, indicates overconfidence as they imply elements of absolute certainty that cannot be known by the searcher. These comments were made by participants with data query backgrounds who performed relatively poorly. These findings support work by other researchers, that we have different (and flawed) mental models of IR systems (Blandford *et al.* 2007, Norman 1983) and probably explain the levels of user satisfaction given.

Question #4: What underlying mechanisms cause differences in search task performance?

Several themes were identified to explain differences in search task performance: task difficulty (information overload), attention, motivation, mental models and metacognitive processes.

Task complexity affected search performance, information overload having a detrimental effect to how many of the high value items were identified by the majority of participants. Where attention levels were low (misread the task question) task performance was low. Some participants appeared highly motivated, perhaps believing a link exists between effort and performance (Vroom 1994) and behavioural traits [B7] support this. One participant who performed well displayed anxiety *"Felt under pressure, wanted to do well, I was worried I may miss something"* [P23].

Where a participant's mental model was relatively accurate (e.g. [P18]), experiential task learning could be low (evidenced by only two queries per task), but the quality of search task performance was (relatively) high. Where a participant's mental model was less accurate (e.g. [P19]) and experiential task learning was high (potentially evidenced by 11 individual queries for Cyprus), which may be taken as high motivation and metacognition, search task performance was (relatively) high [P23]. Problems exist where the participants mental model was inaccurate *and* metacognition was low, leading to no experiential learning (evidenced by a single query), which led to low search task performance.

All participants were aware of wildcards and how to use them, *"Should have thought of wildcards"* [P1] and *"don't know why I did not use wildcards"* [P4]. Perhaps with so many results returned in today's search engines (regardless of whether they contain the most relevant), the thought to add a wildcard to receive even more search results does not come to mind, despite the fact this may surface material which may be even more relevant than that which has been returned already.

When participants were informed about how many of the high value items they had found, it appeared unexpected, participants were surprised they missed the items, *"Unbelievable"* [P19], *"Interesting"* [P6], *"Very useful"* [P21], *"I obviously need to experiment more in the searches"* [P19], *"I will do things differently next time!"* [P25]. Unexpectedly, some participants [P1, P4, P19 and P21] spontaneously performed further searches in the company global library during the actual telephone interview, to locate the missing items based on the new knowledge given. One explanation is the information given disrupted the mental models of the participants causing a suspension of their current beliefs giving way to intellectual curiosity which may have subsequently led to a different way of perceiving things.

It appears that some participants view the unstructured information space (corpus) as 'orderly' (*like a physical library*), whilst others appear to view it as more 'chaotic' (*like a teenager's bedroom*). The view taken, may influence satisfaction, when to stop searching and ultimately search task outcome.

Several participants were adamant they made certain queries when the evidence from the search log indicated they had not [P3, P7, P14, P19 and P21]. This may have implications for search user interface design to prompt and help searchers remember activities they have done, a form of scaffolding (Azevedo and Hadwin 2005), supporting search user interface design features proposed by other researchers (Golovchinsky *et al.* 2012). This is also a good example of how mixed methods research provides insights that a single method would miss. Analysis of only interview data (qualitative) or only search log data (quantitative), would probably not have surfaced the theme of 'forgetting'.

When informed they found none or few of the high value items, two participants [P7 and P9] rejected an alternative to their current mental models. Some felt the task was a little synthetic, not a *"real world situation"* [P7], where they would have more time in a real situation to construct a proper search strategy [P9], or "*would behave differently in a real situation*" [P5]. One participant who had indicated they were satisfied for both tasks, but only found 3 of the 8 high value items, explained *"This is what happens in a library system where you search on metadata, I am not a fan. We should be able to search on the full text of the documents, not rely on inconsistent tagging and metadata"* [P4].

None of the participants were aware of processes to objectively measure and feedback how well exploratory search tasks had been performed. The results were presented to the General Manager for global exploration IM, who expressed surprise at the results with a desire to incorporate findings

in organizational awareness and learning processes. With regards to [B2], the point was made, *"It's very surprising in 2015, that something so trivial is not handled as standard by all search engines"*. An interview took place with the Search CoE manager, reporting to the Chief Information Officer (CIO) line of business. The Search CoE makes training videos available on the search website. However, in terms of formal responsibilities, the comment was made *"We are responsible for making the enterprise search engine work and that people can use it, not whether people are capable of knowing how to search."*

The actual search performance of most participants could be considered relatively poor based on their levels of work experience and job role. It is likely they have not been receiving effective feedback on their exploratory search task performance. Lack of 'systems thinking' (Senge 1990) by senior management, viewing components of search in isolation, not as a connected interdependent whole may be a causal factor. This lack of 'systems thinking' may reveal deeper attitudes and beliefs at CIO levels, with a bias towards *technology capability* rather than *search capability* within the organization.

Transferability

Themes identified from six semi-structured interviews [O1-O6] with organizations in a range of industry sectors were compared to the themes identified in the case study organization. Findings are summarized in a convergence coding matrix (Farmer *et al.* 2006) in Table 8.

Table 8 – Convergence coding matrix for organizational interviews

Contextual theme	Theme meaning			
	AG	PA	S	DA
Surprise at the study finding of poor search task performance		•		
Surprise at the study finding there is no association between user satisfaction and actual search task performance (info. overload)				•
Surprise at the study finding there is no association between self-assessed search expertise and actual search task performance		•		
No organizational measurement or feedback of searchers task performance	•			
Focus on technology capability rather than search capability	•			
Total	**2**	**2**	**0**	**1**

Where AG=Agreement, PA=Partial Agreement, S=Silence and DA=Dissonance

Organizations were surprised (and not surprised at the same time) at the poor search task performance from the case study, evidenced by *"wow that is quite low, in some ways shocking and surprising, [pause] but on the other hand not that surprised"* [O3]. It appears that Search/KM staff which look at search logs or observe search practices are harbouring thoughts of poor search expertise in their organizations. These concerns are not being shared more widely because they feel it is not necessarily their responsibility, evidence is anecdotal and there is no clear owner to inform, *"Nobody takes a strategic overview of search other than making sure the IT service works"* [O3]. A level of dissonance was expressed regarding the lack of a link between user satisfaction and search task performance (for the information overload task). Half of the organizations were very surprised, whilst the other half were unsurprised and presents an opportunity for further research.

When presented with the finding there was no correlation between self-assessed search expertise and actual search task performance, four out of the six organizational participants were very

surprised. One participant commented, *"Interesting. I would probably rate myself as very good, but it would not surprise me if I turned out to be very poor!"* [O1]. Recent changes in mind-sets' were evidenced by, *"CIO has got the message. We are moving search from a nice to have, to something which is intrinsic in everything we do"* [O4] and observations on transferability are made, *"Very interesting for me to see, in the end, search in big enterprises is looking at the same type of challenges."* [O5].

It was found that none of the six organizations measure their searchers task performance or have any feedback mechanisms for exploratory search. These findings support those identified in the case study organization. The data is from a limited sample presenting an opportunity for further research.

Development of a theoretical metamodel

Whilst feedback loops have been included in workplace derived user centric process based information behaviour models (Leckie *et al.* 1996), no prior linkage has been made between organizational learning feedback loops and exploratory search task performance in the workplace. The results from the study are combined with the existing literature in a theoretical metamodel to explain factors for exploratory search task performance (Figure 7).
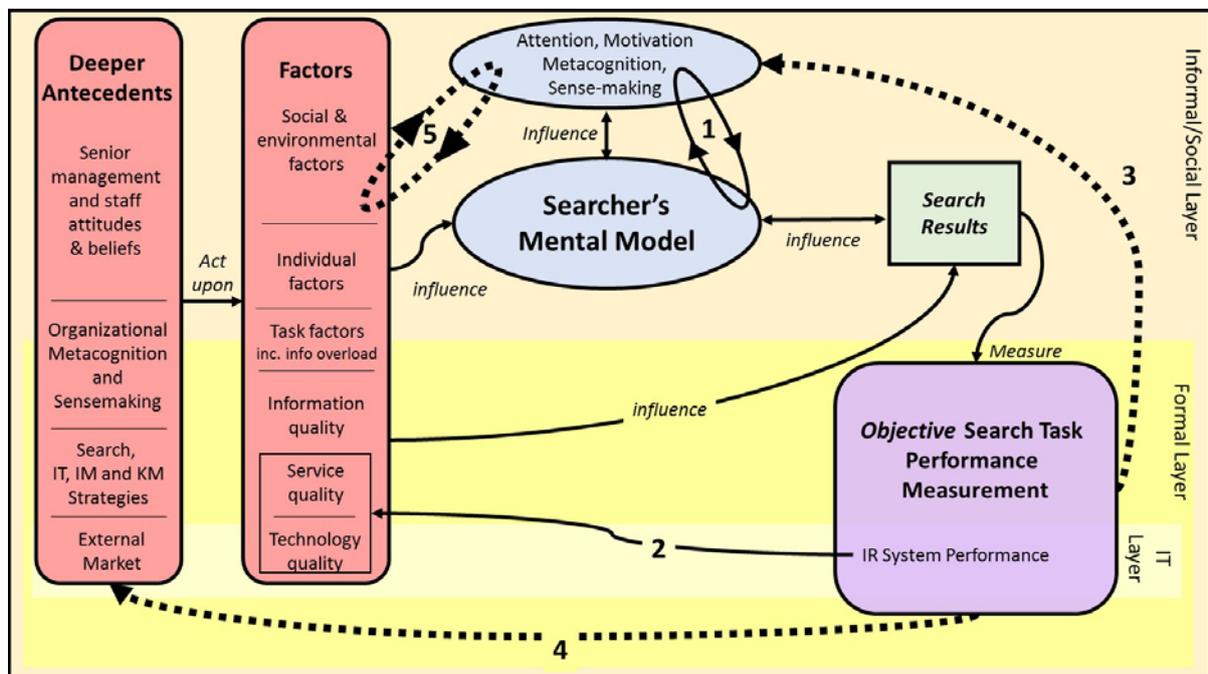
Figure 7 – Causal metamodel for exploratory search task performance in the workplace. Learning processes (labelled 1-5) are overlain, those in dotted lines may be largely missing in organizations

The overall causal model is placed within the three OS layers consisting of the Information Technology (IT) layer, Formal layer (roles, procedures etc.) and Informal layer (behaviours, beliefs etc.). This is further sub-divided using the existing literature to include the factors and antecedents on the left hand side of the model. These factors influence the searchers mental models directly, or indirectly through the use of search technology. Exploratory search task performance may be caused by the searchers mental model or influencing factors and antecedents. Organizational literature points towards technology & search services (White 2012) and information management (Andersen 2012) as the key causal factors for effective enterprise search capability. Evidence from this study indicates mental models and metacognition are also a key causal factor for exploratory search performance.

Five types of learning processes are overlain on the model highlighting the key findings from the study. Those in solid lines appear to occur regularly, those in dotted lines appear largely absent from the organizations studied. The study identified the occurrence of experiential learning (Kolb 1984) (1) where the searcher learns from the search results presented and adapts (Leckie *et al.* 1996), which is a key aspect of successful performance. The literature review and study interviews identified the occurrence of single loop learning (Argyris and Schon 1978) (2) where search logs are analysed and concomitant refinements made to the IR technology or service. Double loop learning cycles (Argyris and Schon 1978) appeared to be absent where objective performance is not fed back to the searcher (3) so mental models could be updated, or fed back into organizational strategies and models (4).

The final learning process that is inferred to be missing is social cognitive learning (5) (Bandura 2001). It appears there is little opportunity for searchers to learn from one another, perhaps explaining the large variance in search performance. These three loops (dotted lines) represent *exploratory search task performance feedback loops that* appear to be largely missing within the organizations studied. As stated by Argote (1999), improved organizational learning may lead to improved business results.

Conclusions

Information overload appears to have a significant effect on search task performance yet the majority of searchers may not be aware. This may lead to premature termination of exploratory search tasks that could lead to sub-optimal business outcomes.

No association was found between self-reported search expertise and task performance. It is possible the simple Likert item used was not adequate as a measurement instrument. Another explanation is that people cannot accurately assess their own search capability and is an area for further research. Persistence, constructing queries effectively, using wildcards where appropriate and effective search result handling contribute to search success. However, forming accurate mental models encompassing the risks and opportunities presented by the information space may be just as critical.

Participants with lower levels of satisfaction for the information overload task (relative to the normal task) found more of the high value items overall. Searchers with more advanced mental models of the information space may be able to grasp how certain factors influence uncertainty. A new theory is put forward, *Relative Satisfaction Theory (RST)*. The theory predicts that searchers who can detect the influence of environmental factors (increase of uncertainty) between two search tasks through their satisfaction attribution, are likely to produce better results than those who cannot.

While research into the concepts of organisational search and information overload is well developed, this paper has highlighted the specific linkages from the empirical data to the theory of organisational learning, by testing and establishing relationships between search task performance and five types of learning process within the context of the oil and gas industry.

Advances in machine learning, semantic networks and enterprise information tagging strategies could make it easier to locate information in the workplace. Mitigating mismatches between the queries used by staff and the information they seek. However, for a variety of reasons such as content structure and availability of statistical data for algorithm deployment within the enterprise, it is likely that search expertise levels will play a crucial role in exploratory search task performance.

The evidence in this study supports a view that the lack of effective *exploratory search task performance feedback loops* in an organization may cause deficiencies in search expertise (literacy). Both searchers and organization may not 'know' that they 'don't know' (metacognition) the quality of their search expertise or search task performance. Organizations could utilize the theoretical metamodel presented to reconceptualise their understanding of search and incorporate the method and behavioural findings in formal 'top down' IL health-check processes. These could be targeted towards staff involved in high leverage, 'high risk' work tasks, where information gathering is crucial.

There may be value in integrating social media tools such as discussion networks more closely with enterprise search tools, enabling staff to automatically 'publish' their search task description, query's and outcomes as they go along, inviting feedback from a trusted community. This 'bottom up' mechanism could stimulate learning, collaborative search and improve search literacy.

Certain search user interface design features may improve task performance. User interface scaffolding could help searchers move from a feeling of being overwhelmed to one of empowerment. For example, a display of all the queries made during a session (and view counts) to mitigate the chances of the searcher forgetting to make queries or thoroughly check results.

Organizations which apply 'systems thinking' to their search capability, moving from reactive event driven, to generative systemic structure explanations, may develop more optimized search environments than those which do not.

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