

Keeping Up to Date: An Academic Researcher's Information Journey

Sheila Pontis

*Interaction Centre, University College London, 2nd Floor, 66-72 Gower Street, London WC1E 6BT, UK.
E-mail: s.pontis@ucl.ac.uk*

Ann Blandford

*Interaction Centre, University College London, 2nd Floor, 66-72 Gower Street, London WC1E 6BT, UK.
E-mail: a.blandford@ucl.ac.uk*

Elke Greifeneder

Berlin School of Library and Information Science, Humboldt-Universität zu Berlin, Unter den Linden 6, Berlin 10099, Germany. E-mail: greifeneder@ibi.hu-berlin.de

Hesham Attalla

Elsevier, Radarweg 29, Amsterdam 1043 NX, The Netherlands. E-mail: h.attalla@elsevier.com

David Neal

*Research Applications and Platforms, Elsevier B.V., Radarweg 29, Amsterdam 1043 NX, The Netherlands.
E-mail: david.neal@elsevier.com*

Keeping up to date with research developments is a central activity of academic researchers, but researchers face difficulties in managing the rapid growth of available scientific information. This study examined how researchers stay up to date, using the information journey model as a framework for analysis and investigating which dimensions influence information behaviors. We designed a 2-round study involving semistructured interviews and prototype testing with 61 researchers with 3 levels of seniority (PhD student to professor). Data were analyzed following a semistructured qualitative approach. Five key dimensions that influence information behaviors were identified: level of seniority, information sources, state of the project, level of familiarity, and how well defined the relevant community is. These dimensions are interrelated and their values determine the flow of the information journey. Across all levels of professional expertise, researchers used similar hard (formal) sources to access content, while soft (interpersonal) sources were used to filter information. An important “pain point” that future information tools should address is helping researchers filter information at the point of need.

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Introduction

Conducting and delivering up-to-date research is key to academic work, but keeping up to date is becoming more challenging: Researchers have to locate relevant information within a body of literature that is growing by millions of new articles per year (Björk, Roos, & Lauri, 2009; Khabsa & Giles, 2014). Many researchers “feel that they do not find all the information on the topic for which they are searching” (Hemminger, Lu, Vaughan, & Adams, 2007, p. 2211). This “information explosion” has changed information behaviors and exposed new problems. Although information is more accessible than 20 years ago, it is harder to get to the “right information as needed at a given time” (Saracevic, 2009, p. 2571). The study reported here aimed to better understand current information behaviors of scholars, their adjustments as a result of information overload, and requirements for improved information services, with a particular focus on how they keep up to date.

In this paper, we present our analysis of in-depth interviews with 61 researchers, in which we investigated their information needs and requirements for future tools. We use the information journey model (Blandford & Attfield, 2010) to frame the data analysis, and build on the work of Wilson and Walsh (1996), and Järvelin and Ingwersen (2004) to identify dimensions involved in the information journey,

how they interrelate, and how the values within each dimension influence the way researchers seek, acquire, and use information. Findings should inform the design of future information systems (e.g., information-seeking tools, dashboards, databases) to support the work of researchers (especially on the activity under investigation).

First we review prior work on behaviors related to keeping up to date, followed by an introduction to the information journey. We examine “dimensions” in the context of information seeking. After presenting the research questions, we describe the method and report the main findings. We discuss initial and emergent dimensions, and how their values shape the information journey. We conclude by identifying future opportunities.

Related Work

Keeping Up to Date

In the academic context, keeping up to date is critical for the development of research projects, writing articles, engaging in debates, and even hiring the right researcher (Jamali & Nicholas, 2008). To keep up to date, researchers use various information resources, many of which have become available online through search engines and web alerts. Many scientific and technical publications, and more recently books, can be relatively easily accessed online (Martin & Quan-Haase, 2013). However, Pontis et al. (2015) found that narrowing down (filtering) the amount of scientific information available was a “major struggle” for researchers. Building on findings from Foster (2004), Pontis and Blandford (2015) report that distinguishing relevant from irrelevant information (authors, discoveries, literature) was an essential first step for filtering information. The work reported here builds on these findings.

This activity has been investigated as an information-seeking task. Investigating PhD students and staff members, Jamali and Nicholas (2008) identified methods for keeping up to date based on researchers’ perceptions of the relevance of the activity, their level of seniority, and the type of research. However, they do not explicitly discuss methods or tools used to filter information, nor examine whether the methods used, their frequency of use, level of seniority, and type of research influence each other. This paper extends the study of how researchers keep up to date from a holistic perspective, exploring how they make information decisions and what dimensions influence that process.

Information-Seeking Models

Prior information-seeking theories and conceptual models abound (Saracevic, 2009). Most have been developed from theoretical perspectives, focusing on information seeking, information retrieval, or information behaviors; and investigating stages/phases, actors, strategies, sources, dimensions/variables (Järvelin & Ingwersen, 2004). Little research has taken a more holistic approach that considers all stages involved when individuals interact with information.

Prior models (Belkin, Oddy, & Brooks, 1982; Niedzwiedzka, 2003; Wilson, 1999) identify the recognition of an information need, information-seeking behaviors, and a stage where information is processed and used, but they do not focus on how information is assessed, interpreted, or filtered within the context of the individual’s knowledge and interests. Although how information is assessed has been addressed separately (e.g., Buchanan & Loizides, 2007), there remains a need to bring these accounts into a coherent framework.

Other models (Ellis, 1989; Kuhlthau, 1991; Kuhlthau, Heinström, & Todd, 2008) add a finer layer to the information-seeking process, proposing more stages and features. They pay little attention to information encountering or activities that occur after the information has been gathered (information use). A newer model, proposed by Robson and Robinson (2013, p. 184), combines prior studies to present “factors that affect information behavior” including: information users’ needs, providers’ needs, motivating and inhibiting factors, characteristics of information, and sources. However, this model does not focus on encountering, active seeking, acquiring, interpreting, and using information. These steps are featured more explicitly in the information journey model (Blandford & Attfield, 2010), which we will introduce here.

The information journey model. The information journey model presents a holistic “understanding of what people really do and how information integrates with their professional and personal lives” (Blandford & Attfield, 2010, p. 29). It identifies activities with information in the context of work or leisure, grouped into four nonsequential phases (Figure 1). The journey does not necessarily begin when the individual recognizes a need because they may encounter information without having previously recognized the need; also, information may not be immediately used: the individual may retain it for future use, or may need to find and interpret further information before any of it can be used.

As individuals interact with information their understanding evolves. The journey describes aspects of information interaction that are often overlooked (e.g., validating and interpreting information, and applying that interpretation to the information task). This emphasizes that information interaction extends beyond information seeking and also includes information encountering, which highlights the intrinsic problem of how people find the right information at the right moment, and should inform the design and development of future information tools.

In prior studies, this model has been used to understand individuals’ information behaviors: in academia and healthcare (Adams & Blandford, 2005), law (Attfield & Blandford, 2011), and marketing (Du, 2014). In this study, it is used to structure the data analysis; insights add detail to its phases: that is, dimensions that shape researchers’ information interactions during the journey. We unpack the concept of dimensions and review related work in the next section.

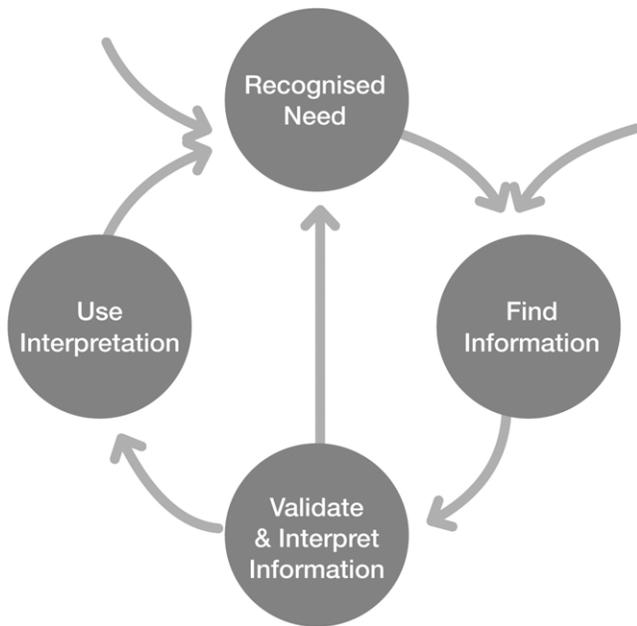


FIG. 1. The four phases of the information journey model (from Blandford & Atfield, 2010).

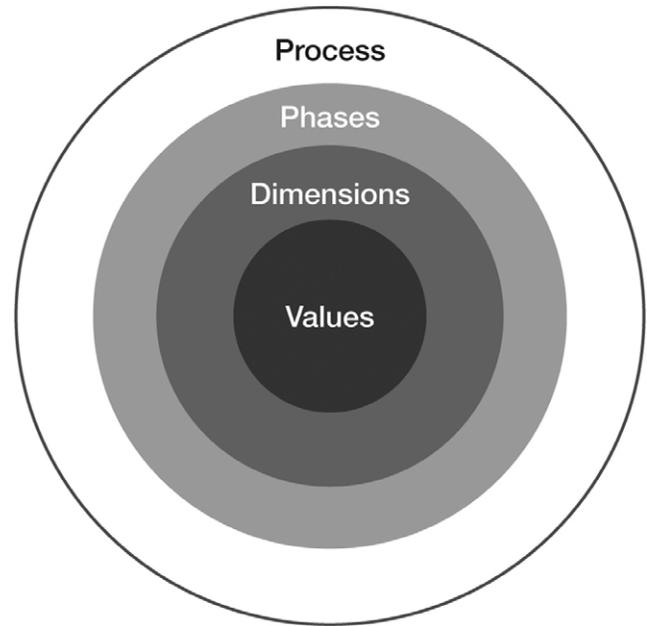


FIG. 2. Component terminologies used in this paper. High-level view of how components involved in a process relate to each other, based on the review of information science theories and studies.

TABLE 1. Dimensions introduced by prior studies.

Wilson and Walsh's (1996) intervening variables or dimensions	Järvelin and Ingwersen's (2004) Dimensions
- Personal characteristics	- Work task dimension
- Emotional variables	- Search task dimension
- Educational variables	- Actor dimension
- Demographic variables	- Perceived work task dimension
- Social / interpersonal variables	- Perceived search task dimension
- Environmental variables	- Document dimension
- Economic variables	- Algorithmic search engine dimension
- Source characteristics	- Algorithmic interface dimension
	- Access and interaction dimension

Dimensions in Information Seeking and Retrieval

Leckie, Pettigrew, and Sylvain (1996, p. 67) suggest that information-seeking behaviors are “the result of a complex interplay of variables.” Likewise, Wilson and Walsh (1996) suggest the existence of “intervening variables” which shape individuals’ information behavior. They organize variables into eight dimensions (Table 1), each including several variables: for example, ease of access, credibility, and channel of communication are variables within source characteristics. The values of these variables determine whether they support or obstruct information behavior (Wilson & Walsh, 1996).

Järvelin and Ingwersen (2004) combined factors from prior studies to present “nine broad dimensions that interact in information seeking and retrieval processes” (Table 1).

Similarly, Johnson (1997) describes “factors” which “determine the underlying imperatives to seek information” (In Robson & Robinson, 2013, p. 175). In his model, seven factors are grouped into three categories: antecedents, information carrier factors, and information-seeking actions. In line with these studies, Kuhlthau’s (1991) and Kuhlthau et al.’s (2008) work introduced sets of feelings and emotions which influence the individual’s behavior, while Niedźwiedzka (2003) and Robson and Robinson (2013) include “context” as an essential element that shapes information behaviors. Although dimensions and variables have been widely discussed in studies of “personality, health communication literature, consumer research, and innovation” (Wilson & Walsh, 1996), those studies do not reveal how dimensions relate to each other, or the values within each dimension.

In this study, the way researchers move through the phases of the information journey is analyzed in terms of values contained in dimensions (Figure 2). Building on the work of Wilson and Walsh (1996), Järvelin and Ingwersen (2004), and Pontis and Blandford (2015), we initially explored two dimensions: researchers’ expertise in academia (i.e., level of seniority) and the type of channels researchers use to access information.

Expertise. Three dimensions of expertise have been found to influence information-seeking behaviors: search, domain, and professional expertise (Chu & Law, 2007; Pontis & Blandford, 2015; Vakkari, 1999, 2002; Warwick, Rimmer, Blandford, Gow, & Buchanan, 2009; Wildemuth, 2004). Search expertise refers to knowledge and skills used to find

required information. Domain expertise is the knowledge an individual has in a specific subject area (Wildemuth, 2004). Professional expertise comprises the experience and skills an individual possesses for performing their role (Pontis & Blandford, 2015). In this study, we explicitly manipulated professional expertise: researchers with diverse levels of seniority in academia; we did not explicitly control for search or domain expertise but, as previous work stresses, there is a correlation between these three dimensions. Participants' level of familiarity with the subject area that they were working on emerges from the analysis as a key dimension, but we did not manipulate that dimension explicitly.

The influence of expertise on information behaviors has been widely investigated (Ellis & Haugan, 1997; Ellis, Cox, & Hall, 1993; Kuhlthau, 1999; Meho & Tibbo, 2003; Palmer, 1991; Warwick et al., 2009; Wildemuth, 2004). Hsieh-Yee (1993) reports a correlation between search and domain expertise. She explicitly manipulates these two types of expertise while investigating search strategies in online search. Exploring the relationship between domain expertise and academics' information behaviors, Brown (1999, p. 29) found that, while most astronomers, chemists, mathematicians, and physicists rely on "the latest issues of journals" to support research activities, mathematicians mostly rely on "monographs, preprints, and attendance at conferences and personal communication." Vakkari (2002) reports that domain expertise influences how individuals filter information (search expertise). Studying PhD students' behaviors, Chu and Law (2007) examine how the necessary information-seeking skills to conduct academic search develop while their domain expertise increases.

Jamali and Nicholas (2008, p. 444) report that domain expertise influences the way scientists search for information, suggesting that scientists from different subfields use different tools, and stressing the need to study "narrower subject communities within disciplines for a deeper understanding of the information behavior of scientists." Hemminger et al. (2007, p. 2205) explore how domain expertise influences "searching, retrieving and reading of scientific scholarly articles." They report that demographic variables (e.g., departments, gender, distance to library) have a stronger influence on information-seeking behaviors (e.g., library use or electronic use, preferences of search interface) than domain expertise.

Information sources. Information can be accessed through formal channels by using information systems or reading a book, or through informal channels by interacting with information intermediaries (asking a colleague, talking to a friend) (Järvelin & Ingwersen, 2004). In this study, formal channels are defined as hard sources, and informal channels are defined as soft sources. Depending on their need, individuals search for information using either or both channels. For Leckie et al. (1996, p. 167) the use of information sources also "var[ies] according to career stage, from student and junior [to] intermediate and more senior stages." Jamali and Nicholas (2008, p. 444–462) suggest that "aca-

demics rely more on personal communications such as word of mouth and conferences for keeping up to date compared to younger researchers."

Although in the academic context published material is frequently accessed through digital libraries, academics do not rely exclusively on hard channels when seeking information. Adams and Blandford (2005) studied the role of information intermediaries. They found that friends, family, and colleagues can influence an individual's information journey by helping them shape the need, providing support to filter information, and facilitating information retrieval. This supports previous studies (Hertzum & Pejtersen, 2000; Tenopir & King, 2004) which have found that information intermediaries played a key role as both sources of knowledge and facilitators for locating relevant information.

Ross (2001) found that most readers developed strategies for choosing a book to read for pleasure based on previous experience and meta-knowledge of authors, publishers, conventions for promoting books, and sometimes on a social network of family or friends, who recommended and lent books. This knowledge is activated when readers browse in a bookstore or library. Pettigrew (2000) analyzed information processes between nurses and elderly patients in community-based clinics, finding that patients were often buoyed by affective and indirect sources of information from nurses, which enabled them to relax in the knowledge that help was available if required. Similarly, Du (2014, p. 1857) reported that "internal people sources" were a key source of information for marketing professionals. This emphasizes the influential role that expertise has in the choice of channels academics make to find information.

Study Aims

This study is part of a broader investigation aimed at validating and prioritizing use cases representing frequent academic activities that have been defined for the "Elsevier Connected" program, and understanding how to best translate insights into product features that support researchers' work. Findings reported here emerged from a detailed study focused on gaining a holistic understanding of researchers' information behaviors to keep up to date, and identifying dimensions that shape that journey. To achieve these aims, we explored the following questions, focusing on keeping up to date:

- How does a researcher' level of seniority influence information seeking?
- What is the role of information intermediaries (soft channels)?
- What other dimensions not initially considered influence the information journey?

Methods

The study was structured in two rounds; first exploring nine use cases that were determined based on prior studies (Jacobson, 2004): keeping up to date, profiling, reviewing,

reading, writing, publishing, connecting, funding, and storing data; then focusing on two of the initial nine use cases which were reported as high priority by the participants: keeping up to date and profiling. We report findings from the first use case. Findings from the second use case will be reported in Greifeneder et al. (in preparation). Each round of the study is explained in detail below.

We utilized semistructured interviews and prototype testing to investigate researchers' information-seeking behaviors based on the selected use cases. This approach helped address the fact that individuals have a partial understanding of their own activities, and consequently often articulate a limited explanation of what they do to a third party (Blandford & Rugg, 2002). During the interviews researchers describe their information behaviors to accomplish each use case—explicit knowledge. To help participants articulate further details—semitacit knowledge (Blandford & Rugg, 2002), they were asked to perform those use cases during prototype testing sessions using a dashboard interface.

Study Design

We conducted pilot tests with 3 participants before each round of the study (6 participants in total). Pilot tests aimed to iron out ambiguities from the interview guide, ensure that all topics could be covered in the allocated time, and anticipate “problem” areas in the test—that is, parts of the prototype dashboard that were not intuitive or concepts that were hard to understand. Findings from pilot tests were used to refine the script and adjust the flow of the studies.

Round 1: Validating use cases. This round aimed at validating and prioritizing nine use cases, and identifying requirements for the design of systems to support the management of scientific information. Sessions lasted between 60 and 90 minutes; they involved a demographic questionnaire and semistructured interviews followed by prototype testing of a dashboard interface. Sessions were conducted face-to-face with participants being interviewed in their workspaces; interviews were audiorecorded and transcribed verbatim, and participants' interactions with the dashboard were recorded through screen capture software.

Round 2: High-priority use cases. This round aimed at gaining a better understanding of the two use cases that emerged as priorities from the first round. We used the critical incident technique (Flanagan, 1954) to structure the session and collect participants' accounts. Sessions lasted 60 minutes; each involved a demographic questionnaire and semistructured interview, followed by prototype testing, think aloud, and a post-task questionnaire. Participants were engaged through WebEx meetings, and all sessions were recorded, and audio-transcribed verbatim.

Participants

Researchers with various levels of seniority and background were recruited from four universities across Europe,

TABLE 2. Overview of participants per round and university included in the analysis.

University		Round 1	Round 2
Europe	N°1	16	16
	N°2	6	18
North America	N°3	12	13
Asia	N°4	14	14
		48	61

North America, and Asia, as summarized in Table 2, through three methods: internal recruitment in each university, advertising the study to academic authors from Elsevier publications, and contacting the Mendeley advisory board. We classified participants into three levels of seniority: PhD students (junior), researchers with a PhD and up to 7 years of postdoctoral experience (mid), and researchers with a PhD and more than 7 years of experience (senior). Participants were working in four different domains: social sciences and humanities, medical and health sciences, natural sciences, and engineering and technology sciences (Table 3).

We assigned a code (letter + number) to every participant. A number is used to indicate the order in which participants took part in the study, while a letter indicates participants' level of professional experience: (J) for junior, (M) for mid-level, and (S) for senior. Throughout this paper, each time we report a specific participant's words or descriptions, we shorten that information using acronyms. For example, J1 denotes the first participant (a junior researcher), and M2 is the second participant (a mid-level researcher).

Data Analysis

We collected data sets from both rounds to build a rich description of researchers' information behaviors and interactions, and identified various sources and tools used for academic daily activities. We illustrate findings with participants' actual words.

Round 1. We first coded interview and audio transcripts using the nine use cases as categories of code. Data extracted for each use case were recoded according to five topics: tools used for dealing with each use case, problems encountered (“pain points”), methods used to deal with pain points, suggestions for new information system tools, and outliers. Coded data sets were examined from three angles: across institutions, by level of seniority, and by participants' background.

Round 2. Data were coded using descriptive and topic coding focusing on the concept of awareness as a key characteristic of keeping up to date, and using a bottom-up qualitative approach. The analysis aimed at creating

TABLE 3. Demographic information of participants.

University	Participant	Gender	Seniority	Background	Field	Round 1	Round 2		
Europe	N°1	1	F	J	Medical Science	Arthritis	Yes	Yes	
		2	M	M	Engineering Science	Human Computer Interaction	Yes	Yes	
		3	M	J	Medical Science	Clinical Neurologist	Yes	Yes	
		4	F	M	Engineering Science	Medical Physics	Yes	Yes	
		5	M	S	Natural Science	Pharmacy	Yes	Yes	
		6	F	S	Engineering Science	Chemical Engineering	Yes	Yes	
		7	F	M	Social Science	Economics	Yes	Yes	
		8	F	M	Medical Science	Alzheimer	Yes	Yes	
		9	M	J	Engineering Science	Fluid Dynamics	Yes	Yes	
		10	F	S	Social Science	Deafness	Yes	Yes	
		11	M	M	Medical Science	Bioinformatics, Evolutionary and Population Biology	Yes	Yes	
	12	M	J	Social Science	Psychology	Yes	Yes		
	13	M	S	Engineering Science	Medical Physics	Yes	Yes		
	14	M	S	Natural Science	Biomaterials	Yes	Yes		
	15	M	J	Medical Science	Neurology	Yes	Yes		
	16	M	M	Natural Science	Nanoscience	Yes	Yes		
	N°2	17	M	S	Natural Science	Analytical and Environmental Chemistry	Yes	Yes	
		18	M	S	Natural Science	Chemistry	Yes	Yes	
		19	M	S	Natural Science	Agriculture	No	Yes	
		20	M	S	Natural Science	Computational Properties of Single Neurons	No	Yes	
		21	F	S	Medical Science	Molecular Biology	No	Yes	
		22	M	M	Engineering Science	Bioinformatics	No	Yes	
		23	M	J	Engineering Science	Computer Science	Yes	Yes	
		24	F	J	Social Science	Psychology	Yes	Yes	
		25	M	M	Social Science	Psychology	No	Yes	
		26	M	S	Medical Science	Neurobiologist	No	Yes	
		27	F	M	Medical Science	Analytical Doctor	No	Yes	
		28	M	M	Social Science	Geography	No	Yes	
		29	F	J	Medical Science	Nutrition	No	Yes	
		30	M	J	Natural Science	Neuroscience	Yes	Yes	
		31	M	S	Social Science	Biological Psychology and Psychophysiology	Yes	Yes	
32		M	M	Natural Science	Agriculture	No	Yes		
33		M	J	Natural Science	Agriculture	No	Yes		
34		F	J	Natural Science	Agriculture	No	Yes		
North America		N°3	35	M	M	Natural Science	Biomaterials and Modification of Biomolecules	Yes	Yes
			36	M	S	Natural Science	Particle Physicist	Yes	Yes
	37		F	J	Natural Science	Virology	Yes	Yes	
	38		M	S	Engineering Science	Electrical and Computer Engineering	Yes	Yes	
	39		F	M	Natural Science	Nuclear Physics	Yes	Yes	
	40		M	J	Natural Science	Chemistry	Yes	Yes	
	41		M	S	Natural Science	Chemistry, Biochemistry	Yes	Yes	
	42		F	J	Engineering	Civil engineering	Yes	Yes	
	43		F	J	Social Science	Literary, Culture and History	Yes	Yes	
	44		M	J	Social Science	Psychology	Yes	Yes	
	45		M	M	Social Science	Psychology	Yes	Yes	
	46		F	S	Social Science	Psychology	Yes	Yes	
	47		M	J	Social Science	English	No	Yes	
Asia	N°4	48	M	S	Engineering Science	Computer engineering	Yes	Yes	
		49	F	M	Engineering Science	Mechanical and Aerospace Engineering	Yes	Yes	
		50	M	S	Natural Science	Biology	Yes	Yes	
		51	M	M	Natural Science	Single Molecule Microscopy	Yes	Yes	
		52	M	M	Engineering Science	Computer Engineering	Yes	Yes	
		53	M	S	Natural Science	Materials Chemist	Yes	Yes	
		54	M	M	Natural Science	Chemistry	Yes	Yes	
		55	M	M	Natural Science	Structural Biology	Yes	Yes	
		56	M	S	Engineering	Product Design	Yes	Yes	
		57	M	M	Natural Science	Physics	Yes	Yes	
		58	M	M	Natural Science	Physicist	Yes	Yes	
		59	M	M	Engineering Science	Power Electronics	Yes	Yes	
		60	M	M	Natural Science	Physics	Yes	Yes	
		61	M	M	Engineering Science	Aerodynamics	Yes	Yes	
						48	61		

Note. Key for table abbreviations: Gender: Male (M), Female (F). Seniority: Junior (J), Mid (M), Senior (S).

TABLE 4. Distribution of participants' background domains and levels of seniority in Round 2.

Seniority		Background			
		Medical sciences	Natural sciences	Engineering sciences	Social sciences
Senior	20	2	10	5	3
Mid	24	3	10	7	4
Junior	17	4	5	3	5
	61	9	25	15	12

categories that correlated with how researchers keep up to date, accounting for information behavior differences and similarities across the three levels of seniority (expertise), and the four background domains (Table 4).

We initially identified 10 categories: (a) type of information sources used, (b) how well defined a domain/community is, (c) state of the project, (d) familiarity with the research topic, (e) type of needs, (f) type of relevant information, (g) years working in an academic context, (h) types of information actions, (i) types of information needs, and (j) information uses. Then we compared and collated these categories to identify those for which meanings were overlapping. As a result of grouping categories, three core themes emerged: (1) researchers going through the four phases of an information journey (Blandford & Attfield, 2010); (2) five dimensions influencing the way they move through the phases of that journey; and (3) a set of values within each dimension that hinder or support information-seeking behaviors in each phase.

Results

In all, 17 females and 44 males participated. Profiles are shown in Table 3. The majority of junior researchers were in the middle and last years of their PhD programs, getting and analyzing data (e.g., J42), writing up (e.g., J1, J24), or completing revisions of thesis drafts (e.g., J9, J43). The experience among mid-level researchers was more varied: some were starting new projects (e.g., M7) or had recently started working as postdoctoral researchers (e.g., M22), while others were senior research associates with 6 or 7 years of experience (e.g., M51, M52). Senior researchers reported a wide range of responsibilities: preparing research proposals (e.g., S21), being journal editors (e.g., S56), directing research groups (e.g., S5, S6, S50), teaching (e.g., S6), and management (e.g., S19).

The understanding of “keeping up to date” was found to vary from one researcher to another. For some, it involves “know[ing] all the relevant facts (. . .) and cit[ing] all the relevant papers for the theoretical background” (J24), “knowing what other similar groups are doing” (J3, J30, S21, S17), “which direction they are following” or “at which stage they are right now” (S13). Participants M58 and M16 explained that having awareness of the latest advances helps to avoid replication:

You have to be well aware of what your competitors are doing, because otherwise you could end up with a lot of data going to waste if you are not quick enough and you are not able to predict the next move from the other labs. [M16]

Learning about “both competitors and also collaborators” (S13) is key for some, as well as learning “complications similar to [their] research questions” (J30). For others keeping up to date involves “looking for things that people have not done yet, or looking at documents in a way that people have not looked at them” (J43), or “knowing what gives the best result right now” (M54).

The majority of participants (23) explicitly reported that this activity is intrinsic to academia but they typically lack the necessary time to perform it separately from other activities. Being able to find relevant and interesting pieces within large amounts of information and the lack of methods to find specific results emerged as the most important pain points for researchers aiming to stay up to date. Consequently, some of the more senior researchers gave up trying to do so because “it takes too much time” (S38, M8), or they just bring themselves up to date when they have a specific need, like writing a grant (S50). Participant M2 reported that:

when you're so busy with writing papers and doing your own project work, just staying up to date with your field as an isolated activity, I don't think it gets done too much. [M2]

This is consistent with findings reported by Jamali and Nicholas (2008, p. 449), who noted that it was important for most researchers to “keep up with the developments of their subfields.” However, they clarified that “the levels of importance were different” between researchers, varying from being “absolutely critical” to “not important at all.” Our study clarifies that one important factor is whether or not the information will be put to immediate use.

Overall, participants across all levels of seniority reported similar pain points, and strategies to seek and access content to keep up to date; four phases which match those of the information journey model emerged from their accounts (this should not be a surprise since the model was empirically derived). In addition to the initial two dimensions—(a) level of seniority and (b) type of information source—three more dimensions emerged as shaping the phases of the journey: (c) the state of the project, (d) the

DIMENSIONS OF THE KEEPING UP-TO-DATE INFORMATION JOURNEY

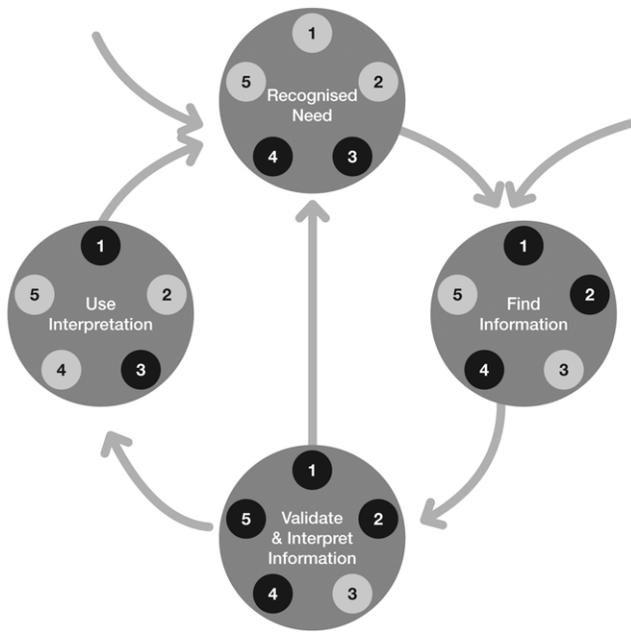


FIG. 3. With different degrees of influence, the five dimensions that emerged from the analysis are involved in each phase of the information journey (based on Blandford & Atfield, 2010). The dominant dimensions of each phase are indicated in black. Dimensions key: (a) level of seniority, (b) type of information source, (c) state of the project, (d) level of familiarity with the current project, and (e) how well-defined the relevant community is.

level of familiarity with the current project, and (e) how well-defined the relevant community is. The five dimensions correlate with each other and their values influence information behaviors in each phase. However, the dimensions have different degrees of influence in each phase (Figure 3). In the following sections, we unpack the four phases and five dimensions involved in keeping up to date, analyzing the influence of the more dominant dimensions in each phase.

Recognized Needs

For keeping up to date, the majority of participants distinguished between a *specific* need: in response to a particular information task, and a *general* need: to maintain awareness of developments in their field. In either case, when participants have a recognized need, they initiate an information-seeking journey. Type of need was often related to level of seniority and degree of familiarity with the topic. Some participants also described encountering relevant information when they were not actively looking for it. Although encountered information “may have potential merit” (Marshall & Jones, 2006, p. 66), participants only described it as relevant when it was immediately useful.

Senior researchers reported three occasions with specific needs: the beginning of a new project (e.g., writing up a paper, leading a new research group), hiring a new

researcher, and finding funding opportunities. Junior and mid-level researchers reported that the state of their current research project determined their motivation and involvement in keeping up to date, and that this activity was not always a priority.

State of the project and level of familiarity. Literature review. The beginning of a new project is “very active for searching” (M49) because researchers are, to some extent, domain novices at this point. Regardless of their level of seniority, researchers focus on gaining an understanding of what has been done in the particular field (J44).

Although researchers frequently review old and new literature, the field of study and the specificity of the project determine the timeframe of published scientific material that researchers are interested in reading. Participants working in subfields of engineering sciences related to IT and computer engineering mostly search for recent publications, which describe newer methods and techniques, rather than older publications (M22; M52). They “read articles no older than two years” (M22). Within the same science domain, but in longer-established fields of study (e.g., mechanical and aerospace engineering), older papers are considered as valuable as newer ones (M49).

Data analysis/prototype development. During hands-on stages, “it’s absolutely crucial to be on top of what’s coming up: what other people are doing” (M39). When the project or experiment is more advanced, researchers are interested in staying up to date with other projects using similar methods or tools to theirs.

Testing/writing up. As the project progresses and researchers gain more familiarity with the topic, both the need and interest in staying up to date decrease. Some mid-level researchers when working on the latest stages of a project can become “lazy” and “largely just rely on [their] colleagues” (M39) to keep up to date.

Find Information

When researchers have a recognized need, either specific or general, they need to *find* a specific piece of information (e.g., a particular paper) or *learn* about something (e.g., a method). Participants reported two major channels used to search for that knowledge: using digital tools (hard sources) and interacting with peers and colleagues (soft sources).

Information sources. In round 1, 43 of 48 participants reported searching the web, primarily using Google, PubMed, Google Scholar, journal websites, and Research Gate, while 32 participants mentioned word of mouth as another method. In most cases, the first response was “quickly brows[ing] through specific feeds [they] get” (S38) followed by the use of more specific tools, like using “very simple keywords in PubMed” (S19). Twenty-seven participants subscribe to journals and specific websites to receive

the latest published papers and articles in a specific field based on keywords. Sixteen participants reported using social media (Twitter, Facebook, and blogs), while others combined hard and soft sources, using multiple methods.

Although no significant differences emerged across participants from different backgrounds, the use of soft sources varied across levels of seniority. Here, we will analyze their use per level.

Information sources, levels of seniority, and familiarity. Senior researchers rely on soft sources the most, regardless of background domain or level of familiarity with a project. While all 20 senior researchers reported the use of digital tools and databases (e.g., Google Scholar, Research Gate, automatic news from journals), 14 of them also stated that interactions with peers and colleagues were essential to know what was happening in their fields. They argued that conversations with peers provided invaluable insights:

The most important information is information that's not yet published. So, this is discussion groups with my colleagues in a very early stage of doing research. (. . .) Most important is to talk to the people, because they tell you much more (. . .) We talk about more than is published or you'll find in databases. It's sharing ideas. [S21]

Furthermore, participants working in niche communities highlighted keeping “an eye on people working in a very similar direction” (S17) as almost the only way to learn about the latest developments or specific techniques. Similarly, participant S26, a neurobiologist, stressed that this type of information would not be available in published papers or the web:

Whether anybody else is doing the same things as I am, and so that just means knowing the five people in the world who might be using the same method, and most of that is not available online in any fashion, it's just getting to know those five people or asking whether they're doing the same kind of work and how they're doing it, and this is something that you learn through word of mouth more than anything else. [S26]

Interactions with information intermediaries can occur inside or outside the direct network of colleagues. Frequently, more senior participants reported connecting with research groups working on a similar line of investigation but not directly related to them.

The role of soft sources emerged as particularly relevant when researchers need to “search for people, like a postdoc or a research fellow to work for [a] project” (S56). This participant explained that he “contact[s] [his] friends who are in a similar area, and then ask[s] them if they have PhD students, or they have some people to recommend.” Similarly, when participant S19 needed to find “programs for funding” he turned to his research department, hoping to find a list with funding opportunities related to his research interests, instead of conducting an open search online. This finding expands prior studies (Adams & Blandford, 2005;

Du, 2014; Tenopir & King, 2004) exploring the role of colleagues and peers to facilitate obtaining timely information.

In line with the work by Jamali and Nicholas (2008), attending conferences was described as another channel. However, it was perceived differently according to participants' level of seniority. More senior researchers were interested in attending conferences to talk to colleagues and learn about “unpublished” information. Conversely, less experienced researchers typically attended conferences to learn about novel discoveries and methods, or have access to the latest papers that are hard to find otherwise.

In contrast to more senior researchers, 16 of 24 mid-level researchers considered journal articles more important than information from intermediaries. All mid-level participants reported the use of hard sources as the main channel to search for information and keep up to date. Nine of them mentioned having “discussions” (M16), “group meetings” (M4), and “chit-chats” (M61) with their colleagues to “discuss different papers” (M4). Only participant M39 reported that she would “largely just rely on [her] colleagues,” because “they will send e-mails to everybody if they find an interesting paper.”

All 17 junior researchers described using search engines as the main method, but six also reported learning what is going on in their fields through information intermediaries, often more senior peers or their mentors:

My personal network of people I've met at conferences or faculty or other graduate students, like in conversation with them to find out what people are doing, or who's doing what where. [J43]

It really comes from colleagues and other people recommending, picking up the papers and then passing them round our department. [J3]

Similarly, participant J37 reported that “most of the literature is recommended to [her] by lab mates or [her] advisor.” In this case, information intermediaries provide guidance and recommend literature to help more junior researchers get familiar with their project fields.

Validate and Interpret Information

Most participants stressed that there is not enough time to read and process all the available online and offline (e.g., in conferences) information using current information systems (e.g., e-mail subscriptions, online searches). Participant S46 stated that “[they] all have finite resources, and if [they] spend all [their] time being a consumer, there's no time to be a producer.” Filtering encountered papers and websites emerged as the major pain point across all levels of seniority.

Levels of seniority, familiarity, and information sources. More junior researchers reported that the difficulty when dealing with great amounts of information was to discern what papers were the core ones, and which facts

were the relevant ones that should be cited. They did not point out problems with reviewing particular papers or judging whether something was relevant based on what they read:

You are a PhD student, you are not familiar with many things, especially the literature, whatever you find, you probably read and you do a filter: okay, this is good, this is not good. But how we can know that these are a key reference, like there should be some software to tell you. [J15]

Participant J3 suggested that having the possibility to “actually tailor the research that is being sent to you, to really meet your kind of sub area” would help filter information he encounters online. This indicates the need for a resource (soft or hard) to help more junior researchers identify key references for their projects. Mentors, thesis directors, peers, and more senior colleagues frequently play this role.

Unlike junior participants, mid-level participants validate their findings “based on [their] personal judgment” because “there’s no standard way to see whether [something] is relevant or not” [M60]. This is in line with findings reported by Pontis and Blandford (2015): Professional expertise gives researchers the confidence to make decisions based on their own knowledge.

Mid-level participants also stressed that having access to a growing number of scientific publications and receiving many alerts but lacking a way to distinguish relevant from irrelevant ones makes it hard to read everything that might be relevant. Like junior researchers, participants M8 and M11 expressed the need to feel in control and to tailor the search according to their needs:

It’s a huge job to try and keep up to date because there are so many journals, so many articles published all the time, so you need some kind of filtering system like that. [M8]
I think by about halfway, I’d probably give up. There has to be a better way of . . . not necessarily summarizing these, but maybe limiting it to the most recent articles that have been published, or something like that (. . .) I need to be in control of how I access, and what pieces of information I wish to see. [M11]

More senior researchers have means to filter information that less experienced researchers have not. For example, some are editors of journals, which gives them access to unpublished manuscripts. These manuscripts highlight current hot topics and trends in research (S56). The case of participant S19, briefly described earlier, also illustrates that access to resources is not equally available to all. To optimize the search and filter information regarding new funding opportunities, he communicated with the leader, the head of the research department, and the Vice President of Research. As a result, dedicated staff was allocated to work on those tasks.

Across the three levels of seniority, participants reported that talks and meetings with peers and attending conferences

were ways to verify the quality of information and identify key pieces. “Weekly lab journal discussion club” (J44, J42) meetings are often organized by senior researchers to encourage peer dialog among their team, and provide an overview of what is happening in the field. Participants S50 and S53 explained that less experienced researchers have an active role in these meetings by presenting recent publications that are of interest to the group, but everyone learns something from recently developed new directions. Social interactions were reported to be sources of knowledge that provide valuable insights for filtering and validating information.

Degree of definition of the community. Some academic communities and fields of study are more clearly defined than others. According to the type of community and research project participants work on, the perception of keeping up to date and managing information varies from being “not very hard” to being “a huge job.” When the area of work is “quite small” or “quite a niche” (e.g., J34, J42, M2, M4, M22, S50, S17), researchers often “know most of the academics who are working in [their] area, so it is not very hard to keep up to date” (S10). In these cases, participants reported gaining awareness by checking a reduced number of journals (two to four journals), or the work of key people (S26) and research groups in any part of the world that are working on the same subarea as them.

While participants working on niche subfields or communities did not report filtering information as a pain point, they emphasized the lack of relevant papers, as a consequence of having “very specific interests” (M22). Conversely, when the area of work involves broader communities, participants across all levels of seniority argued that keeping up to date with all the literature was hard or impossible. The volume of scientific content being published demands time to manage and digest, as participants S38 and S50, a computer engineer and biologist, respectively, explain:

That’s a time issue. I don’t pretend to do a very good job at it, partly because the things I’m interested in are so broad, it’s extremely difficult to stay up to date in a comprehensive way. The biggest answer to it is I really don’t stay up to date and it takes too much time. [S38]
I can’t possibly really keep up to date. I mean in the sense that I don’t have that much space in my head! [S50]

Use Interpretation

When keeping up to date, information can be used in many ways, from having an awareness of what competitors and peers are doing or making better sense of a research question to writing up a paper or thesis. In this context, the result of “being up to date” may not have “direct ‘use’ outcomes” (Blandford & Attfield, 2010, 32), as in the first two cases. Participants’ level of seniority, and the state of the project determine whether, how, and when encountered information is used.

Level of seniority. When researchers find relevant information in response to a need, the way that information is used varies depending on researchers' levels of seniority. Some junior researchers use newly published information as soon as they find it in a "direct" way: update their draft dissertations (J9) or determine to what extent it can be applied to what they are currently working on (J12). More senior researchers use encountered information in a "less direct" way to: double-check that the work they are doing is not being duplicated (M16), evaluate the direction that their research projects are going in (S14), or translate the information into new techniques to improve the course of their projects (M52, S13).

State of the project. When participants encounter relevant information without having a recognized need it can be immediately used or saved as reference for future use, depending on whether the information is aligned with the state of their current project. This finding is in line with Marshall and Jones's (2006, p. 66) work that argues that "encountering unexpected, but potentially valuable, information may interrupt us rather than help us complete the current task." Similarly, participants reported that, if the moment is not appropriate, they do not use the information but may save it for later.

I'm on the writing up stage, so even if I did find new techniques I couldn't really use them right now. [J1]

Supporting findings reported by Marshall and Jones (2006) and Pontis et al. (2015), saving information for later use does not guarantee use because individuals either forget that they have stored potentially useful information somewhere or never find the right moment to retrieve it (M2). Participant J3 stressed that when he can "tailor the research that is being sent to [him] to really meet [his] kind of sub area," he is more likely to find relevant information to be immediately used. This indicates that both relevance (specialized information) and timing (when information is encountered) greatly influence information use and follow-up actions. In line with Wilson (1999) and Marshall and Jones (2006), participants reported that they circulate scientific papers they found but do not use to other researchers who may consider them useful (J3, J15, M39),

Discussion

We have presented and structured our findings according to the phases of the keeping up-to-date information journey. We have identified the filtering of information as a major pain point and five dimensions that influence researchers' information-seeking behaviors. In this section, we discuss the values contained in each dimension, and how values can alter behaviors. We analyze how dimensions are associated and how they map to the phases of the journey.

Dimensions and Values of the Keeping Up-To-Date Information Journey

The way researchers interact with information to keep up to date was found to depend on five interrelated dimensions involved in the information journey, illustrated in Figure 3. In order to understand the relationship between these dimensions and the phases of the journey, we have summarized the dominant dimensions in each phase. From this analysis, we identified possible values within each dimension (Figure 4) that influence the way researchers access, find, filter, and use information, supporting Wilson and Walsh's theory (1996) that variables can support or obstruct information behavior.

Dimensions are interrelated, and the values of each influence the flow of the information journey. We found marked differences in information behaviors between junior and senior researchers, but that difference was less noticeable between junior and mid-level researchers, and between mid-level and senior researchers. Mid-level researchers with more than 6 years of experience reported behaviors similar to senior researchers.

When researchers have a recognized need for keeping up to date, that need is related to the state of their current project and level of familiarity with it (Dimensions 3 and 4). At the beginning of a project in which the subject matter is unfamiliar, researchers' domain knowledge is low, which increases their need to get up to date and deepen their understanding. At this stage, researchers from all levels of seniority behave in similar ways because they are unfamiliar with the key resources for that particular subject area. This is in line with Wilson and Walsh's model (1996), which states that a low level of domain knowledge can be a barrier because the individual is not aware of the relevant information resources, while a high level of domain knowledge

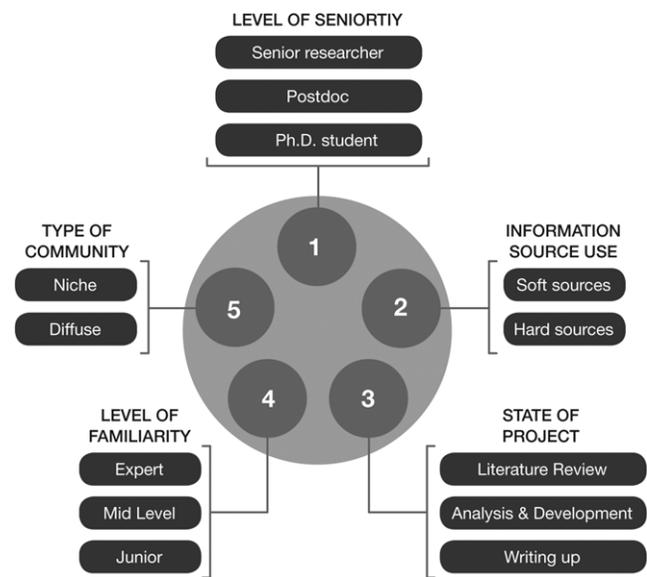


FIG. 4. Possible values for each dimension, which can influence researchers' information behaviors when keeping up to date.

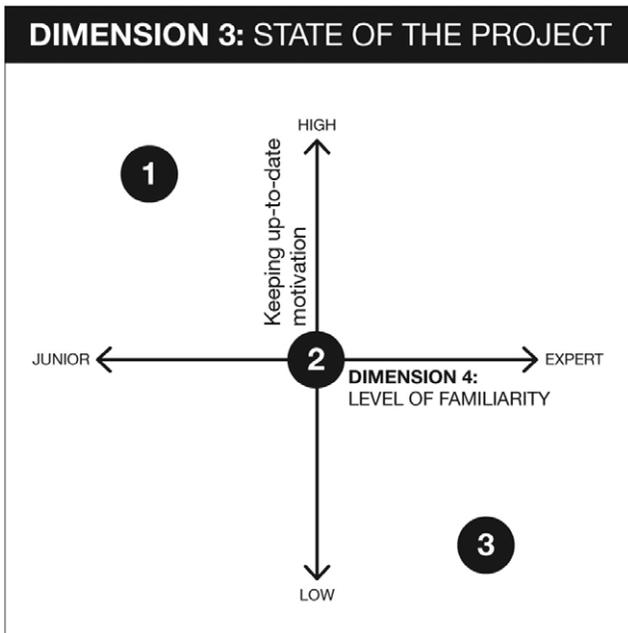


FIG. 5. The values of the state of and the level of familiarity with a project can determine whether researchers are more or less motivated to keep up to date. Key: (1) Literature review (2) Data Analysis and Prototype Development, (3) Writing up.

supports information behavior. As the project evolves, researchers' level of familiarity increases, and they become more aware of the relevant sources and important journals, as well as key scientists and research groups. Conversely, their motivation to keep up to date decreases (Figure 5).

As researchers move forward in the journey, the level of seniority (Dimension 1) determines the information-seeking methods used (Dimension 2). Junior researchers, who have a low level of expertise, mostly search the web to find relevant information, and also expect recommendations from more senior peers and mentors about essential literature they must read. Junior researchers have not fully developed trust in hard information sources because their level of familiarity with them is low (Robson and Robinson, 2013, p. 173) (Dimension 4). As researchers gain expertise, they still mostly use hard sources to find information but their awareness of key sources increases and their relationship with peers changes. The role of information intermediaries is not to provide recommendations of must-read literature but to discuss similar interests or recommend interesting articles to each other. When researchers have high levels of expertise, social interactions provide them with richer insights than reading journal papers and they value discussions with peers for keeping up to date. Senior researchers also use hard sources, but only when they need to find a particular article or piece of information (Figure 6).

When validating and interpreting information, more junior researchers find that ready access to information makes it harder to identify relevant authors and references. For more senior researchers, the rate of publication of

		DIMENSION 4: LEVEL OF FAMILIARITY			
		EXPERT		JUNIOR	
		DIMENSION 2: INFORMATION SOURCES USE			
DIMENSION 1: LEVEL OF SENIORITY	SENIOR	SOFT	HARD	SOFT	HARD
	MID	SOFT	HARD	SOFT	HARD
	JUNIOR	SOFT	HARD	SOFT	HARD

FIG. 6. The values for Dimensions 1, 2, and 4 are strongly interrelated. The values of Dimensions 1 and 4 determine the type of information source (soft and/or hard) used by researchers.

scientific information translates into a need to spend time managing the content. The former do not have the necessary expertise or knowledge to filter information on their own, and often rely on peers and supervisors to help (Dimensions 1, 2, and 4). The latter do not have enough time to read everything that is being published, and often decide not to actively keep up to date or to exclusively rely on social interactions during conferences or meetings.

The degree of clarity with which an academic community or field is defined can harden or soften this situation (Dimension 5). The production of scientific publications in niche communities is smaller than in larger communities because fewer researchers are working on similar projects. Participants working in niche communities did not report difficulty to stay up to date. Furthermore, they mentioned that they were familiar with other research groups in the community, and interacted with them to keep abreast of the latest developments, but they found it hard to find relevant papers because they can be hidden among irrelevant papers. The larger the research field is, the larger the production of scientific material and the number of scientists working on it (Figure 7). Nevertheless, both niche and diffuse research communities reported the need for methods to filter information and find what they are looking for.

The use of the information encountered throughout the journey varies according to whether it has been found in response to a need. Researchers' level of seniority (Dimension 1) influences the way information is used. For more junior researchers, encountered information feeds directly into their work, while for more experienced researchers it is used more indirectly to reflect their current projects. The state of the project (Dimension 3) influences the immediacy with which information is used. Researchers from all levels of seniority are most likely to use encountered information when it is found at the right moment (Erdelez, 1999). Otherwise, information may be forwarded to other researchers or saved for later use: for example, the beginning of a future similar project.

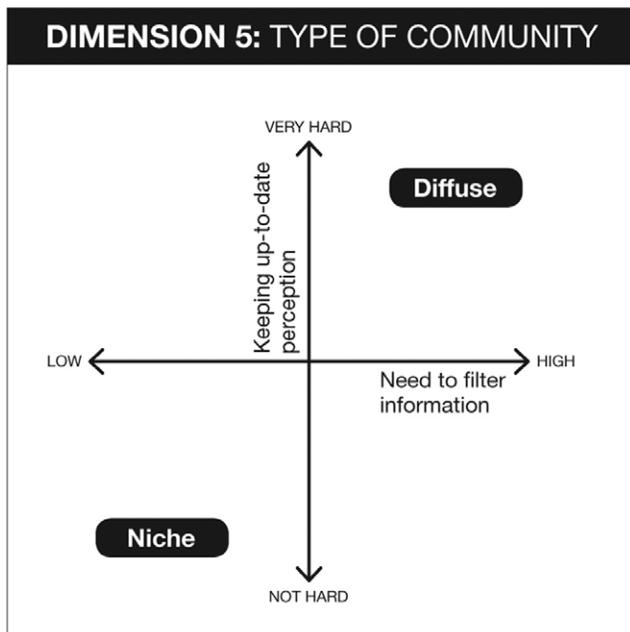


FIG. 7. The two values for Dimension 5 influence researchers' perception of the keeping up-to-date activity, and need to filter information.

A Need for Filtering Tools

Adams and Blandford (2005, p. 167) found that researchers "have more interest in support within the facilitation of information" (Find information phase). While researchers' access to information has greatly improved in the last decade, the research reported here indicates that academics now have a greater need for support to filter information (Validate and Interpret information phase), rather than having more digital search tools. Researchers need a way to control a search by tailoring it to their interests in order to find and use the required information at the given time. Current information systems and tools do not allow the same level of customization as talking to colleagues and peers. Consequently, researchers rely on social interactions for recommendations, finding, validating, and filtering information.

Social interactions evolve throughout researchers' careers from mentor-student to peer-peer relationships. In both cases, information intermediaries emerged as playing a fundamental role to filter information either to help distinguish good from poor content or to gain key insights during conversations that help in choosing one direction rather than another.

A limitation of this study is that the keeping up-to-date activity was investigated in experimental settings, and not by observing researchers performing the activity in a real-life situation. Although we investigated researchers across various domains, we have not fully explored their information-seeking behaviors across subfields.

Conclusion and Further Work

This study explored the information journey of researchers when keeping up to date from a holistic perspective. We have provided details on how the journey starts when a specific or general need is recognized, triggering information-seeking behaviors. We identified the phase of validating and interpreting information as the most important pain point of the journey, needing further support to help researchers cope with the volume of information produced. Finding relevant information at the point of need is essential for it to be used rather than stored away and forgotten. Five dimensions intrinsic to the academic context were found to influence the flow of this journey. We examined the dimensions individually, and provided an analysis of their values and how they correlate with each other, describing how these dependencies and values shape the information journey. Having a holistic understanding of how the journey components (phases, dimensions, values) are associated with and influence how each other contributes to a better understanding of researchers' information-seeking behaviors and needs.

Further explorations and comparisons between researchers of different fields of study would shed light on the degree of influence of each dimension and their values. The next steps could also investigate each dimension further. The implementation of the reported findings in the design of information systems would help identify characteristics that an information-management tool could have to further support academic activities (e.g., customizable filtering options).

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