Thirty-two years of research on information foraging theory: Evolution, key contributions and emerging directions

Williams Ezinwa Nwagwu[1,2]
[1]Department of Data and Information Science,
University of Ibadan, NIGERIA
[2]Department of Information Science, University of South Africa,
Muckleneuk Campus, Pretoria, SOUTH AFRICA
e-mail: willieezi@yahoo.com
ORCID ID: W.E. Nwagwu: 0000-0002-5225-2934

ABSTRACT

This paper examines the evolution and future directions of Information Foraging Theory (IFT) research over the past 32 years (1992–2023). The findings reveal a sustained interest in IFT, with an average of 14 publications per year, culminating in a total of 449 papers authored by 933 researchers. Key contributors such as Peter Pirolli and Margaret Burnett have significantly shaped the field. Initially rooted in cognitive psychology and human-computer interaction (HCI), IFT has since expanded its influence to domains including information science, organizational behaviour, and machine learning. Core concepts of IFT, such as information scent and information patches, have been empirically validated, reinforcing their importance in understanding user behaviour. Publication trends highlight a peak in research activity around 2012, followed by fluctuations and a recent resurgence. The prominence of conference papers reflects the dynamic and rapidly evolving nature of the field. Keyword analysis identifies research clusters focusing on human decision-making, user interfaces, information retrieval, visualization, social networking, and behavioural studies, demonstrating the interdisciplinary application of IFT. Emerging themes such as cognitive load, uncertainty, virtual reality, and big data point to promising new research directions. This overview underscores IFT's significant contributions and ongoing relevance in understanding of human information-seeking behaviour and optimizing systems to meet user needs.

Keywords: Information Foraging Theory (IFT); Information behaviour; Human Computer Interaction (HCI); User behaviour; Cognitive psychology.

INTRODUCTION

Foraging refers to the behavioural process by which organisms actively search for, identify, and acquire resources, primarily food, from their environment. This complex activity involves decision-making mechanisms aimed at optimizing energy gain, minimizing energy expenditure, and reducing exposure to risks such as predation or environmental hazards (Stephens & Krebs, 1986). Foraging behaviours are shaped by multiple factors, including habitat type, resource availability, competition, and evolutionary adaptations (MacArthur & Pianka, 1966). The dynamics of foraging are further influenced by environmental variability and both intra- and interspecific competition (Pyke, 1984). In both human and non-human populations, foraging strategies have evolved to exploit diverse ecological niches efficiently, allowing species to adapt to fluctuating ecosystems and uneven resource distributions (Bell, 1991). These strategies not only ensure individual survival but also play a critical role in shaping population dynamics, predator-prey interactions, and overall ecosystem stability (Sih, 1984). Understanding these behaviours provides valuable insights into ecological processes and the adaptive mechanisms organisms employ in response to environmental challenges.

Research on foraging was initially driven by the study of animals, as early ecologists and biologists sought to understand how organisms interact with their environments to meet their nutritional needs (MacArthur & Pianka 1966; Stephens & Krebs 1986). These investigations focused on how animals optimize food acquisition while balancing energy expenditure, predation risks, and environmental constraints. Early work in this field laid the foundation for understanding the decision-making processes involved in foraging, such as when, where, and how to search for food. Studies of birds, insects, and mammals provided valuable insights into foraging patterns and behaviours, particularly through the observation of predator-prey dynamics and resource competition (Pyke, 1984). The principles derived from animal foraging research, such as optimal foraging models, aimed to quantify how animals maximize energy intake per unit of effort. These models showed that animals make trade-offs between the energy gained from food and the energy spent searching and handling it, which became key to understanding broader ecological interactions (Stephens & Krebs, 1986).

Animal foraging behaviour was further systematized into the Optimal Foraging Theory (OFT), which proposed that animals optimize their foraging strategies by balancing the energy costs of searching for food against the energy gained from consuming it. This theory provided a framework to predict animal behaviour in diverse ecological contexts and became foundational in behavioural ecology (MacArthur & Pianka, 1966). OFT emerged in the 1970s, primarily developed by anthropologists and ecologists to elucidate the food-hunting behaviours of animals. OFT posits that animals aim to maximize their energy intake relative to the time expended in foraging activities (Pyke et al., 1977). It asserts that predators evaluate the energetic costs and benefits associated with different prey types, leading to the pursuit of those that offer the greatest energy return. Consequently, animals continuously assess the energy content of potential food sources and the energy required for consumption, which influences their decision to remain in a particular foraging area or seek alternative food sources (Krebs & Davies, 1987). By selecting varied environments and food options, animals optimize their foraging strategies to maximize overall profit (Stephens & Krebs, 1986).

The principles of biological foraging have inspired a parallel in human behaviour known as information foraging, where individuals seek, gather, and process information efficiently, much like animals optimize their search for food. Valone's (1992) research on hummingbirds offers valuable insights into the adaptive nature of foraging behaviours, illustrating how these small birds adjust their feeding strategies to optimize resource use in dynamic environments. The study demonstrated that hummingbirds effectively balance energy intake against the energetic costs of flight, employing highly flexible foraging tactics based on resource availability and competition. They were observed to adjust their behaviour according to the spatial distribution and quality of nectar sources, responding to environmental changes by increasing foraging frequency or selecting more energy-dense resources. This behavioural adaptability highlights the evolutionary benefits of refined foraging strategies, enabling hummingbirds to maintain energy balance and enhance survival in ever-changing ecological landscapes.

Several studies have since supported Valone's (1992) findings, revealing that humans employ strategies similar to those of animals when seeking information, with the goal of maximizing informational value while minimizing the effort required to obtain it. Pirolli and Card (1999) formalized this idea through the concept of "information foraging," comparing human behaviour in navigating complex information environments to the optimal foraging strategies observed in animals. They found that individuals naturally gravitate toward paths that offer the highest "informational return" for the least cognitive effort. Bryant (2014) further expanded this analogy, showing that in digital environments, users adaptively adjust their search patterns based on the perceived cost and benefit of acquiring information. More recent studies by Yen et al. (2024) and Fok et al. (2024) continue to validate this comparison, illustrating how humans apply adaptive strategies similar to biological foragers, not only in online searches but also in complex decision-making tasks. These findings collectively underscore the cross-domain applicability of foraging principles, highlighting the universality of resource optimization strategies across species and contexts.

Information foraging is a specialized concept within the broader domain of information behaviour, focusing on how individuals optimize their search for information by maximizing value while minimizing effort. This process involves adaptive strategies where users evaluate and navigate between different "information patches" (e.g., websites, databases) based on anticipated returns, drawing a parallel to animals foraging for food. Unlike information-seeking behaviour, which emphasizes the cognitive and emotional processes involved in recognizing a need and searching for information (Wilson, 1999), or browsing, which is exploratory and often driven by curiosity rather than efficiency (Marchionini, 2006), information foraging highlights cost-benefit decision-making throughout the search process.

Over time, insights into human information-seeking behaviours have culminated in what is now known as Information Foraging Theory (IFT). However, a comprehensive analysis that systematically maps the scholarly literature on this theory, particularly its growth, interdisciplinary adoption, and evolving research trends, remains limited. Such an analysis could illuminate how research on information foraging has progressed from its origins in cognitive psychology and human-computer interaction (HCI) to influence diverse fields, including information science, organizational behaviour, and machine learning. Understanding this trajectory would offer valuable insights into how IFT has contributed to theoretical advancements and practical applications across multiple disciplines, deepening our appreciation of its relevance and potential future directions.

This paper presents an analysis of the research trajectory of information foraging over the past three decades. By examining its growth and interdisciplinary impact, the research aims to uncover insights into future directions for information foraging studies and their applications across diverse fields. To achieve these objectives, the study addresses the following questions: What has been the annual publication trend on the topic over the past 32 years? What types of publications contribute to the body of knowledge in this area? What emerging research issues can be identified through a visualization of keywords in the IFT literature from 1992 to 2023?

LITERATURE REVIEW

Understanding the Information Foraging Theory

IFT was formalized by Pirolli and Card (1999), who drew upon biological foraging principles to explain how humans interact with information in a way that mimics the food-foraging strategies of animals. The theory presents a novel perspective on how humans seek and gather information. Drawing inspiration from OFT in biology, Pirolli and Card conceptualize IFT to better understand how individuals search for and gather information. They emphasize the challenges faced by information seekers in an environment flooded with vast amounts of information and constrained cognitive resources. Observing that traditional models of information retrieval, often focused on static systems, fail to account for the dynamic nature of human behaviour, they introduce an ecological approach. This approach accounts for how users adapt their strategies to maximize the value of information gathered while minimizing the effort expended. According to them, individuals engaging in activities such as searching for health advice, product reviews, or social media updates demonstrate behaviours similar to foraging, continually weighing the effort needed to obtain information against its perceived value. In digital environments, where vast amounts of information are readily accessible, users depend increasingly on search engine structures, algorithms, and relevance indicators to navigate efficiently through information (White & Horvitz, 2009). This has underscored the importance of IFT in the development of search tools, databases, and digital interfaces designed to help users manage information overload and make more informed decisions (Bawden & Robinson, 2009).

At the core of IFT are several key concepts. One of the central ideas is the concept of an “information patch”, which mirrors the idea of a food patch in biological foraging. Just as animals seek out areas with abundant food, humans search for clusters of related information. Another important concept is “information scent”, which refers to the perceived value of a source of information based on cues such as links, abstracts, or summaries. These cues help users assess whether a particular information patch is worth further exploration. The theory also introduces “patch models”, which describe how users decide whether to remain within a current information source or move on to a new one. Patch models explore how long users should stay in an information patch, while diet models focus on selecting information sources that maximize the rate of information gain. This decision-making process resembles an information diet, where the goal is to balance the time spent extracting information with the time spent searching for new information patches. Pirolli and Card developed mathematical models to predict how users allocate their time and attention based on the information scent and the expected value from different information patches.

Numerous studies, as discussed in the subsequent paragraphs, demonstrate that users' behaviours align closely with the predictions of IFT. These findings suggest that users instinctively adapt their strategies to maximize the efficiency of information acquisition and optimize their rate of information gain. For example, when the information scent is strong, users tend to stay longer within an information patch, extracting more information before moving on. Conversely, when the information scent is weak, users are more likely to switch to a new source in search of better yields. The practical applications of IFT are extensive. By understanding how users forage for information, designers can create more effective information systems, search engines, and interfaces. The theory suggests that information systems should be designed to enhance information scent, making it easier for users to assess the value of information patches quickly. Additionally, optimizing the layout and structure of information to align with natural foraging behaviours can lead to more efficient and satisfying user experiences.

Pirolli and Card emphasise that IFT offers a robust framework for understanding and predicting human information-seeking behaviour. They advocate for further research to integrate cognitive and ecological approaches, which could refine the theory and expand its applications. Their work (Pirolli and Card, 1999) suggests that combining insights from both fields can deepen our understanding of the complexities of human information behaviour and provides a valuable framework for examining how humans seek and gather information. By applying principles from OFT, Pirolli and Card offer a new lens through which to view information-seeking behaviour, with significant implications for the design of information systems and interfaces. The theory's emphasis on information scent and patch models, supported by empirical evidence, makes it a valuable tool for both researchers and practitioners in the field. In his book *Information Foraging Theory: Adaptive Interaction with Information,* Pirolli (2007) builds on his earlier work by exploring how humans adaptively and efficiently seek, gather, and process information in data-rich environments. Pirolli (2007) highlights practical applications of the theory, particularly in designing information systems and interfaces that align with natural foraging behaviours, enhancing user experience and efficiency. His work bridges ecological principles and cognitive science, offering a robust framework with significant implications for information system design and evaluation.

Empirical Studies on Information Foraging Theory

Early studies on IFT laid the groundwork for understanding how individuals seek, gather, and utilise information, initially focusing on non-digital contexts such as ecology and animal behaviour. Over time, the scope of IFT has shifted towards digital applications, including web navigation, human-computer interaction (HCI), and cognitive models.

The foundational study by Valone (1992) investigated the information-seeking behaviour of black-chinned hummingbirds (*Archilochus alexandri*) in artificial resource patches. The research aimed to determine whether the birds relied solely on current patch-sample information or combined it with prior knowledge about resource distribution to assess patch quality. Valone established two environments with differing levels of patch variability to study foraging behaviour. In the low-variance environment, most birds effectively combined prior knowledge with current patch-sample information, leading to more efficient foraging. In the high-variance environment, however, some birds integrated both types of information while others relied exclusively on current patch samples, with no significant difference in foraging efficiency. Interestingly, the use of prior information emerged only after the birds had explored approximately 25 patches, indicating a strategic shift influenced by experience.

Building on such foundational studies, Bergman and Beehner (2023) introduced the concept of "*information ecology"*, which examines how animals use information to enhance fitness. Their framework poses three central questions: What information is available? How is it used (or not)? And why is it used (or not)? They advocate for a unified approach to studying information use in animal behaviour, emphasising the value of information and the importance of integrating field-based and laboratory-based research methods for a more comprehensive understanding.

Another important study that focused on non-digital application is in respect of social information search, cooperation and competition. Nakayama et al. (2020) examined heuristic rules people use in social information search through a controlled experiment. Participants searched for specific objects in images, either cooperatively or competitively, and used information about objects collected and time spent to decide their next steps. The study found that people paid more attention to others and distributed their search efforts more effectively when cooperating than when competing. These findings highlight the social dynamics of information foraging and the importance of cooperation in optimising search strategies.

In early empirical research on the area, Cunningham and Connaway (1996) deployed IFT to study information-seeking behaviour and information retrieval systems of computer scientists, revealing a preference for browsing and citation searches over traditional indexing schemes. The study highlighted the limitations of existing retrieval systems and emphasised the need for designs that support immediate, office-accessible resources. This research demonstrated the practical implications of IFT for improving information retrieval systems to better align with users' foraging behaviours.

One of the earliest applications of IFT was in HCI and web navigation was conducted by Czerwinski et al. (1998). They investigated the effectiveness of various web page attributes such as titles, summaries, and graphical images, as retrieval cues in navigation tasks. The study found that titles were the most effective cues, primarily due to the text-centric design of browsers at the time. This finding emphasized the need to optimize web interfaces to align with users' cognitive models and suggested that integrating visual cues could further enhance navigation efficiency.

Building on this work, Pirolli (1998) examined IFT's application in information retrieval and computational methods. He introduced dynamic programming as a tool for analyzing information foraging technologies, focusing on the Scatter/Gather text clustering browser. Pirolli's study revealed the complex trade-offs between browser speed, text clustering quality, and task conditions. This approach demonstrated the value of dynamic programming in exploring interactions between design features, task requirements, and user strategies, advancing the understanding of information foraging in technological contexts. Continuing in their seminal attention to research on IFT, Pirolli and Card (1999) developed computational cognitive models, such as ACT-IF, to simulate user behaviour in information foraging tasks. They evaluated interfaces like the Scatter/Gather browser and the Butterfly interface for navigating scientific literature. The models demonstrated that users employ heuristics to optimise their information foraging, validating IFT's applicability in designing and evaluating information access technologies.

In recent years, Illingworth and Thomas (2022) investigated how pre-search belief updating impacts the perceived value of information sources. Through an experiment involving a hypothesis-testing task in medical diagnosis, they demonstrated that shifts in beliefs about disease hypotheses systematically influenced test preferences. This finding emphasises the significance of hypothesis-guided search, shedding light on how pre-search processes shape information-foraging behaviour and the critical role of belief updating in decision-making. Barack et al. (2023) investigate decision-making processes in humans and monkeys, focusing on latent feature learning. The study designed a task where participants made a series of choices to uncover hidden shapes on a grid. The results showed that both species preferred selecting tiles expected to be informative early in trials, a behaviour consistent with foraging patterns. The study found that the speed of learning shapes was predicted by how well participants' choice sequences matched the foraging pattern. This research highlights the adaptive search for information and its role in supporting goal-directed behaviour.

Diwanji et al. (2022) conducted a think-aloud study to investigate developers' information-seeking behaviour on Stack Overflow. They found that participants faced challenges due to the platform's noisy and redundant content. The study identified specific cues associated with participants' actions, which could inform the design of better information retrieval tools and strategies to reduce cognitive load and improve efficiency. Wang & Liu (2024) use expectation-confirmation theory to study users' perceptions of search gain and cost in interactive information retrieval. Their findings show how users' perceptions of gain and cost are influenced by contextual features and in situ experiences. They highlight the complex relationships between gain/cost, expectations, and dwell time, offering insights for user modeling and evaluation in human-centered IR. Wu et al. (2024) examine live streaming shopping platforms, focusing on how live interactivity affects viewers' utilitarian and hedonic values, leading to purchase intentions. They find that live interactivity enhances product diagnosticity, sensory appeal, and entertainingness, which in turn boosts purchase intentions. Their study contributes to understanding the dynamics of live streaming shopping and viewer engagement.

On ontology, knowledge graphs and scholarly research, Nguyen et al. (2020) conducted a literature survey on identifying ontologies relevant to the scholarly and research domains, focusing on modeling knowledge graphs to support researchers in various roles. They identified 43 relevant ontologies, with 35 sufficiently documented for reuse. Through analysis of curriculum vitaes (CVs) and activity logs of senior researchers, they formulated competency questions and created a high-level conceptual model to answer these questions via a holistic knowledge graph. The study identified overlaps and gaps in existing ontologies and proposed preliminary solutions for addressing them. This work emphasises the importance of reusable ontologies in enhancing information foraging for researchers.

Early in the study of cybersecurity, and malware detection, Westland et al. (2020) developed an analytic model to understand the cost-benefit tradeoffs of automatic attack generation and detection using IFT. Their three-phased model suggests that cumulative malware detection has a productive period before the rate of gain flattens, with potential increases as detection mechanisms evolve. They validated their model using anti-virus tools to detect thousands of Trojans over five months, confirming the model's validity and pointing to future research directions. This study highlights the dynamic nature of information foraging in cybersecurity and the need for continuous adaptation and improvement of detection mechanisms.

In the field of software development, Adeli et al. (2020) explored how delivering the right information at the right time and place can reduce cognitive load and enhance accuracy in code comprehension tasks. They conducted a user study using Synectic, a non-traditional IDE featuring linkable annotations, and compared it to the traditional IDE, Eclipse. The findings revealed that Synectic improved accuracy and reduced cognitive load while maintaining usability. These results suggest that spatially organized information can significantly enhance developers' information foraging and code comprehension processes. The rise of social media and concerns about information credibility provided Drias and Pasi (2020) an opportunity to propose an Information Foraging-based approach to assist users in finding relevant and credible information. They developed a social media information foraging system that operates on social graphs, factoring in users' interests and social interactions. Using a dataset from Twitter, they evaluated the system's performance in delivering tailored information paths while ensuring the credibility of the content. This study highlights the potential of IFT to enhance both information retrieval and credibility assessment in social media environments.

Similarly, in the domain of information retrieval and Q&A platforms, Sedhain et al. (2022) applied IFT to Stack Overflow, a popular platform for developers. They designed a semi-supervised model to recommend optimal information, enabling users to locate relevant questions and answers more efficiently. This application of IFT reduces the cognitive load and time developers spend searching for information, ultimately improving productivity and problem-solving capabilities.

Alongside the same pathway, Briggs et al. (2022) explored the impact of a progressive dialogue system on the sensemaking process of intelligence analysts within a cognitive immersive environment. The study highlighted that tools such as collaborative brainstorming exercises, informed by intelligence analysis training literature, could enhance analysts' cognitive schema. The anticipated integration of a progressive dialog function aims to create a more cohesive link between information foraging and sensemaking behaviours, potentially improving the efficiency and effectiveness of intelligence analysis.

An innovative application is the study Arora et al. (2022) which investigated how children and adolescents with Autism, ADHD, and co-occurring Autism+ADHD process repetitive and changing stimuli. Using eye-tracking, the study presented stimuli to participants aged 7-15 and assessed their attention to repeating versus changing stimuli. The results showed that autistic features were associated with longer looks to repeating stimuli and shorter looks to changing stimuli, especially for more complex stimuli. This suggests that individuals with autism may have difficulties processing complex or unpredictable information, which could inform strategies for designing better educational and therapeutic interventions.

In the field of cognitive science and intelligence analysis, Briggs et al. (2022) investigated the impact of a progressive dialogue system on the sensemaking processes of intelligence analysts within a cognitive immersive environment. The study emphasised that tools such as collaborative brainstorming exercises, informed by intelligence analysis training literature, could strengthen analysts' cognitive schemas. The proposed integration of a progressive dialogue function aims to establish a more cohesive link between information foraging and sensemaking behaviours, thereby enhancing the efficiency and effectiveness of intelligence analysis. In a related domain, Drias et al. (2022) introduced an innovative approach that combines IFT with Elephant Herding Optimization (EHO) for information retrieval on social media. Their enhanced EHO algorithm, tailored for large-scale data, incorporates novel operators such as territory delimitation and clan migration through clustering. Extensive experiments using a dataset of over 1.4 million tweets demonstrated the method's effectiveness in identifying relevant information and its superiority over traditional algorithms like the ant colony system and particle swarm optimization.

In the field of computer science and web content organization, Kuznetsov et al. (2022) introduced *Fuse*, a browser extension designed to help users collect and organize web content in a compact, card-based sidebar. By externalizing users' working memory, *Fuse* facilitates the simultaneous extraction and structuring of key information. A 22-month public deployment, followed by user interviews, provided valuable insights into users' structuring behaviours during information foraging tasks, demonstrating how *Fuse* can enhance information organization and support decision-making processes.

In a related area of computer science applied to gender studies, Sedhain et al. (2024) examined the foraging behaviours of developers on GitHub. Using a gender-balanced think-aloud lab study, the researchers analysed how developers navigate repositories and identify bugs within projects. The findings revealed distinct cues and strategies employed by male and female developers. These insights have significant implications for improving gender inclusivity and enhancing user experiences on code hosting platforms by tailoring interfaces to accommodate diverse foraging behaviours.

Further in the area of computer science, Yen et al. (2024) examined how generative AI and web search converge to impact programmers' problem-solving processes. Through interviews with eight experienced programmers, they identified three major challenges and decision-making stages. They proposed a process model encompassing decision-making stages, the information-foraging loop, and cognitive activities during system interaction, offering a framework to optimise the use of these tools in programming.

In psychology/conspiracy theories, Hattersley et al. (2022) proposed a hypothesis to explain why people who endorse conspiracy theories exhibit reasoning biases. They found that belief in implausible conspiracy theories was associated with reduced information sampling in an information-foraging task and less reflective reasoning. This suggests that reasoning biases in conspiracy theorists may result from the need to reduce dissonance between their beliefs and broader data, highlighting the complexity of reasoning processes linked to conspiracy belief. Naito et al. (2022) followed by investigating how social learning facilitates efficient information search in unfamiliar environments. Participants engaged in multiple foraging sessions in spatially correlated reward landscapes, revealing that paired participants improved their search efficiency more than solo participants. The study's computational analysis indicated that social interaction enhanced participants' understanding of the common generative rule, thus improving across-task learning and information search efficiency.

Still on psychology but applied to learning and curiosity, Kedrick, Schrater and Koutstaal (2023) examined the role of curiosity in learning, focusing on the process of self-generated questioning. Their "Curiosity Question & Answer Task" paradigm involved participants generating questions in response to incomplete factual statements and foraging for answers. The study found that high-quality questions increased curiosity, motivated participants to pursue related information, and improved memory retention. This research underscores the importance of active-curiosity-driven learning and the value of self-generated questions in the learning process.

In education/gaming, Avvisati and Borgonovi (2023) investigate the information foraging behaviours of daily gamers during a computer-based science assessment. The study used data from the Programme for International Student Assessment (PISA) to analyse differences between daily gamers and other students. The results showed that daily gamers displayed more active exploration behaviours and spent less time reading instructions. The study suggests that gaming behaviours can influence performance in procedural science knowledge and provides insights for educators and assessment developers on incorporating gaming-inspired strategies into educational assessments.

The application of IFT in core information science is demonstrated by Fok et al. (2024), who introduced *Marco*, a mixed-initiative workspace designed to assist knowledge workers in extracting and analyzing information from business documents. *Marco* reduces the cognitive load associated with extracting and structuring information, thereby enhancing decision-making processes. A usability study revealed that *Marco* enables users to complete tasks more quickly and efficiently while maintaining accuracy. A design probe with domain experts further underscored *Marco*'s potential in various real-world workflows. Liu and Azzopardi (2024) explored user interactions with search interfaces, focusing on biases and heuristics that influence the search process. Their tutorial discussed cognitive biases and heuristics, as proposed by Tversky and Kahneman (1983), and their implications for search decisions in contexts such as health and finance. The authors aim to enhance the design and evaluation of information retrieval systems by accounting for these cognitive factors. Madaio et al. (2024) investigated how AI practitioners learn responsible AI (RAI) in workplace settings. Through interviews with AI practitioners and educators, they identified key learning pathways, including information foraging and interpersonal learning. The study highlighted the importance of socio-technical approaches to RAI education that align with organizational priorities, offering valuable insights into supporting practical RAI learning.

In journalism/data presentation, and marketing/e-commerce, Cao et al. (2022) examined how design strategies in data journalism impact users' reading efficiency and information foraging behaviour. By extracting structural and semantic features of information clues, the study demonstrated how different types of clues affect users' information foraging at various levels. These findings provide valuable insights for improving the design and presentation of data journalism to enhance user engagement and comprehension. Additionally, Xiao et al. (2023) apply IFT and the elaboration likelihood model (ELM) to live streaming e-commerce. By collecting and analysing Douyin's (Tik Tok application for China) live streaming data, the authors found that product interpretation duration, popularity cues, and herding information significantly influenced sales performance. The study constructs a synthetic model to show how live streaming information cues impact viewers' decision-making through central and peripheral routes. This research expands the understanding of live streaming e-commerce and provides practical suggestions for improving sales strategies.

MATERIALS AND METHODS

This study employs a bibliometric approach, with a crucial step being the selection of an appropriate database. Data was collected from Scopus, a comprehensive database of international research that helps bridge the knowledge gap between developing and developed nations. The inclusion of open access content in Scopus highlights the growing significance of open access publishing, making research findings accessible to scholars worldwide, regardless of their institution's financial resources. Scopus was selected for this research due to its extensive coverage and multidisciplinary reach, making it a critical resource for academic studies. As one of the most widely utilised bibliographic databases, Scopus provides comprehensive indexing across science, technology, medicine, social sciences, and the arts and humanities. Its ability to offer broader coverage compared to other databases ensures robust citation analysis and access to a diverse range of scholarly content (Yang & Meho, 2007; Martín-Martín et al., 2018; Schotten et al., 2017). These features underscore its relevance and utility for this study.

Information seeking, Information retrieval, Knowledge discovery, and *information exploration* can be considered synonyms of information foraging. The search was conducted using the syntax "INFORMATION FORAGING." The end date was specified as 2023, and Scopus determined the start date based on the earliest works on the subject. The search encompassed all resource categories covered by Scopus. Scopus includes a built-in facility to extract data on publication year, authors, document type, subject area, and keywords, which were analyzed using this tool. For further analysis, the complete dataset was exported in CSV format.

Data analysis was conducted using Scopus's built-in analytical tools, which provided insights into the annual volume of publications, highlighting trends, peaks, and declines over the study period. The Scopus platform also facilitated the analysis of document types (e.g., articles, reviews, conference papers) and subject areas (e.g., computer science, psychology). Visualization and mapping of keyword co-occurrence were carried out using VOSviewer, which revealed clusters, links, total link strength, and occurrences. The clusters were analyzed to identify dominant themes and emerging issues. The "Avg. Pub. Year" feature in VOSviewer indicated the average publication year for a set of documents, offering a sense of how recent or older the research is.

RESULT

This study was designed to analyse the annual quantity of publications on IFT from 1992 to 2023, analyse the document types, by subject areas and disciplinary spread, and the co-occurrence of the keywords to understand the pattern by clusters, links, total links, occurrence and emerging issues in the area. This study covers a period of 32 years. A total number of 449 papers, a mean of 14 per annum was written during the period. A total of 933 authors, or 2.3 authors per paper accounted for the research in the area. Peter Pirolli is the most prolific, with 30 documents. Margaret Burnett follows with 21 documents. Authors such as Yacine Drias and Saeed Kuttal have each contributed 12 documents, indicating their significant involvement in the field. Other notable contributors include Ross Bellamy, Bonnie E. John, and Daniel Piorkowski, each with 10 documents. Stuart Card and Ninghui Niu have each authored 9 documents, while Leif Azzopardi, Steven D. Fleming, and Charles Scaffidi have each authored 8 documents. There are other authors, each contributing between 3 to 7 documents, reflecting a diverse group of researchers contributing to the study of information foraging.

Annual Quantity of Publications on the Subject

Figure 1 depicts the annual number of publications on information foraging from 1992 to 2023. Initially, during the early 1990s, the field garnered minimal attention, with the number of publications lingering around zero. This period of low activity persisted until the late 1990s, reflecting a nascent stage for research in this domain. As the new millennium approached, there was a noticeable uptick in interest. From 2000 to 2006, the quantity of publications began to rise steadily. This gradual increase indicates a growing recognition of the importance and relevance of information foraging in academic circles. By 2006, the number of publications had climbed to approximately 15, signaling a growing interest in the field.

The most notable change occurred between 2007 and 2012. During these years, the number of publications increased significantly, peaking around 2012 with approximately 35 publications. This peak marks the height of research activity, suggesting that information foraging had gained considerable attention within the academic community. Researchers were actively exploring and expanding both the theoretical and practical applications of this concept. However, this increase was followed by a decline. From 2013 to 2016, the number of publications began to decrease, although it remained within the range of 20 to 30. This decline may reflect a phase of consolidation, where earlier research was thoroughly explored, and the field was stabilizing. The fluctuations during this period indicate a phase of adjustment as the initial momentum began to level off.

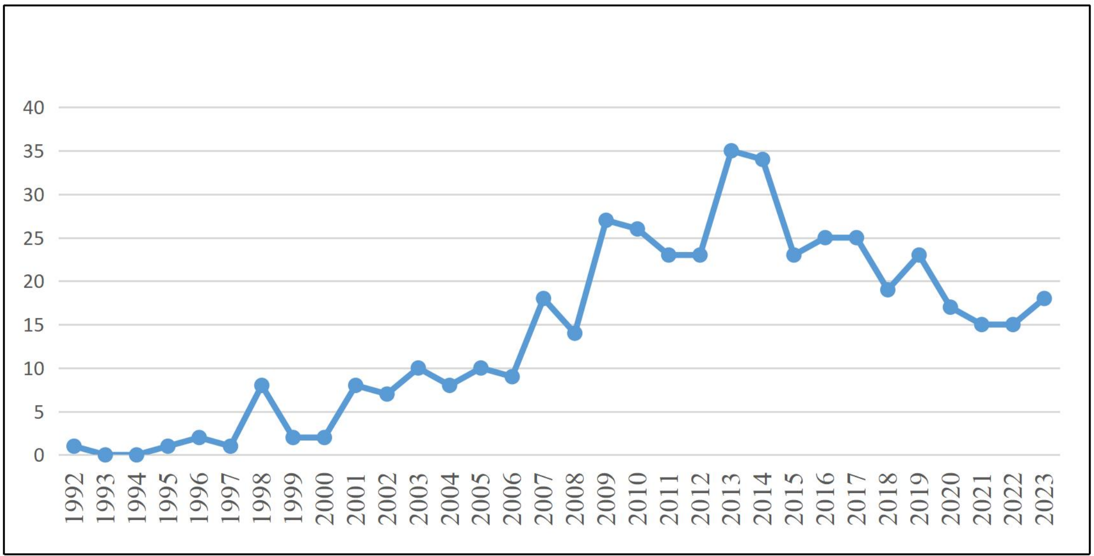

Figure 1: Annual quantity of documents on IFT in Scopus 1992-2023

In the years from 2017 to 2022, the downward trend continued, with the number of publications dipping to around 5 by 2020. This significant drop suggests that either interest in the field had diminished or research had become more specialised and less frequent. However, towards the end of this period, there was a slight resurgence, with an increase in publications by 2022. This hints at a possible renewed interest or new developments within the field that reignited academic attention. The data shows that the field of information foraging experienced a slow start, a period of rapid growth and intense interest, followed by a decline and stabilization. The recent slight increase in publications could signal new avenues of research or a revival of interest in the topic.

Publication Types

This field has garnered significant academic interest, with conference papers being the most common publication type, totaling around 250. This suggests that information foraging is a prominent topic at conferences, where researchers actively share and discuss their latest findings. Journal articles follow closely (about 150 publications), reflecting a solid base of peer-reviewed research that strengthens the field. Review papers (approximately 30) indicate the accumulation of research, synthesizing existing knowledge and offering guidance for future work. Conference reviews (around 10) capture key discussions from major events, ensuring important developments are documented. Books and book chapters (about 5 each) reflect deeper, more comprehensive explorations of information foraging, with the latter contributing to broader edited volumes. Finally, data papers, the least common (1 publication), suggest an emerging focus on open data and collaboration within the research community. These trends collectively interpret the growing recognition and multidimensional exploration of information foraging across various academic platforms.

Documents by Subject Area

Figure 2 illustrates the distribution of documents on information foraging across various subject areas. The data reveals a clear concentration of research efforts in specific fields, with some areas showing significantly more activity than others. As expected, Computer Science dominates the landscape, with nearly 400 documents. This overwhelming number suggests that information foraging is most relevant and extensively studied within this discipline. Given the nature of information foraging - originally rooted in understanding how humans search for and process information - its strong association with computer science makes sense. Researchers in this field are likely focusing on algorithms, human-computer interaction, and data retrieval systems, all of which are central to understanding and optimizing information foraging behaviours. Trailing far behind but still notable are the Social Sciences, Engineering, and Psychology, each with a substantial but significantly smaller number of documents. These fields contribute around 50 to 100 documents each. In the social sciences, the focus might be on understanding how people interact with information in social contexts, while in psychology, the interest could be in the cognitive processes behind information seeking and usage.

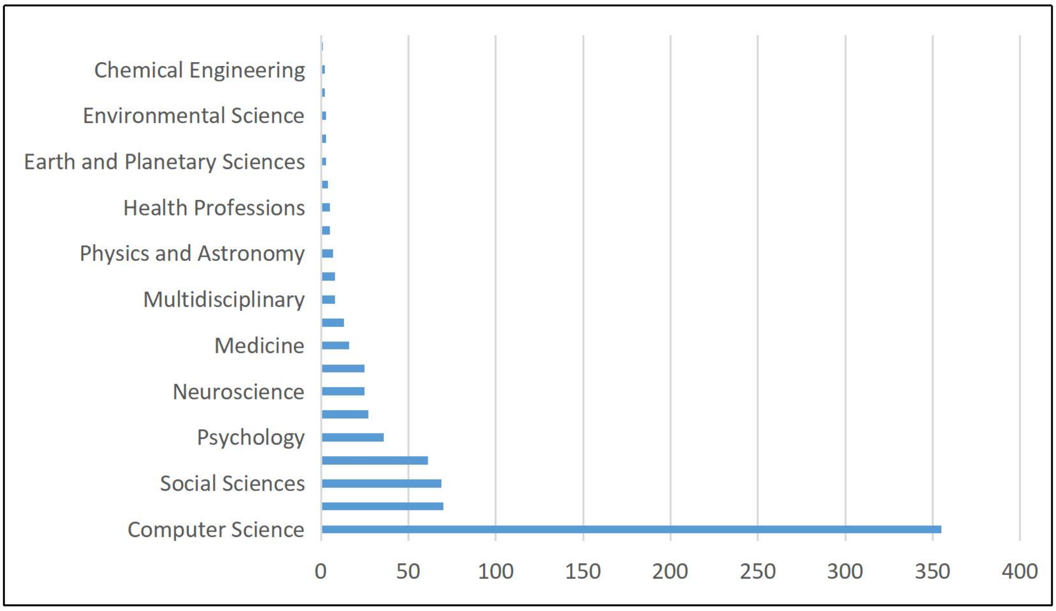

Figure 2: Publications on IFT in Scopus by Subject Area

Neuroscience and Medicine also feature, albeit with fewer documents, approximately 20 to 30 each. Research in these areas may delve into the neural mechanisms of information processing and the application of information foraging principles to medical information systems and patient data management. Other fields, such as Multidisciplinary Studies, Physics and Astronomy, Health Professions, Earth and Planetary Sciences, Environmental Science, and Chemical Engineering, show minimal activity, each contributing fewer than 10 documents. This suggests that while the principles of information foraging might have some relevance, they are not a primary focus in these areas. The inclusion of Multidisciplinary Studies indicates that there is some crossover and integration of information foraging concepts across various fields, though to a limited extent. This may reflect collaborative efforts to apply these principles in innovative ways beyond their traditional scope. The figure shows that information foraging is predominantly a topic of interest within computer science, reflecting its foundational relevance to the discipline. There is also notable but lesser interest in social sciences, engineering, and psychology, with even smaller contributions from a diverse range of other fields. This distribution underscores the central role of computer science in advancing research on information foraging, while also showing the interdisciplinary potential of the concept.

Visualization of All keywords in the IFT literature, 1992–2023

The landscape of information foraging research is a dynamic and interconnected web of themes and concepts, as illustrated in the keyword map. Figure 3 reveals that at its core is the central theme of information foraging, a concept inspired by the animal kingdom, where creatures seek food with minimal effort and maximum efficiency. This idea has been effectively applied to human information-seeking behaviors, navigating vast digital landscapes to locate necessary knowledge. Surrounding this central theme is an intricate interplay of related concepts. Navigation and empirical studies are prominently featured, underscoring the importance of understanding how users move through information spaces and the empirical foundations of these studies. Research focuses on the mechanics of human interaction with information systems, aiming to design more intuitive and efficient tools. In this context, software engineering and software design (green cluster) are critical, focusing on creating systems that facilitate seamless information foraging, much like designing a well-organized pantry that makes it easy to find essential ingredients.

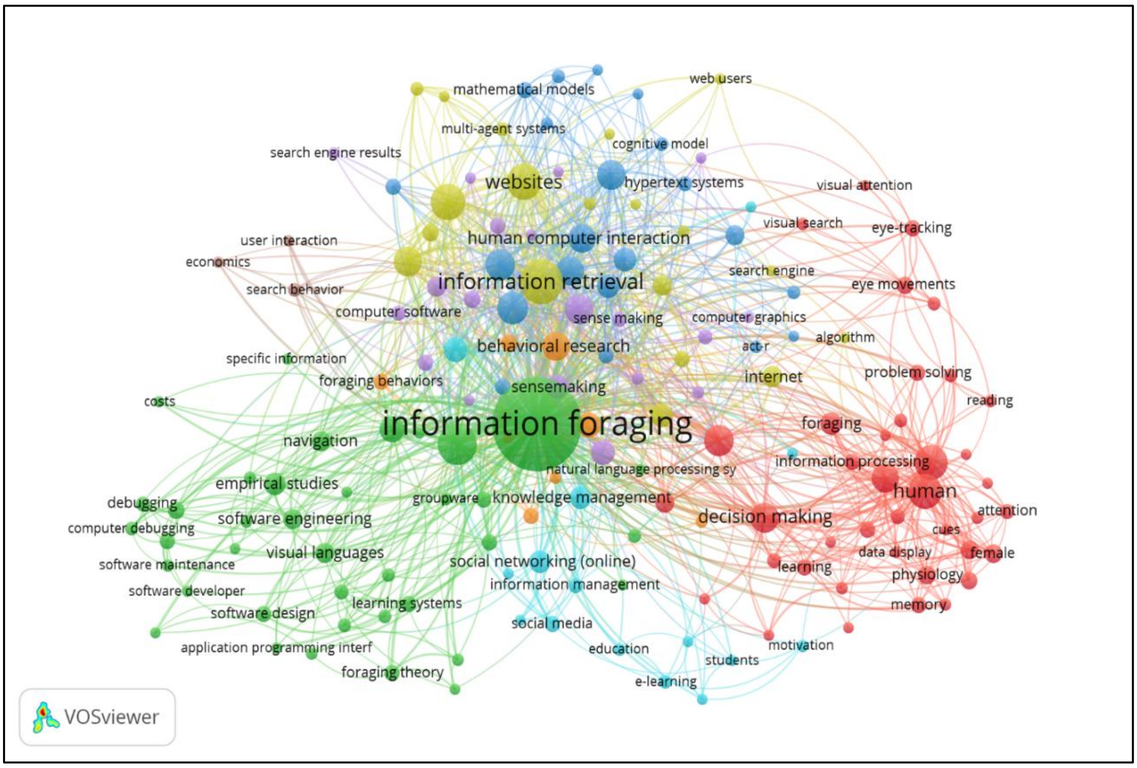

Figure 3: Visualization of Keyword Map of Information Foraging Research Theme, 1992–2023

Expanding from the central theme, the concept of information retrieval (blue cluster) takes prominence, emphasizing interactions with digital interfaces. HCI plays a pivotal role in this area, examining user engagement with websites and search engine results. The primary objective is to streamline these interactions, enabling efficient access to desired information. This cluster also integrates the concept of sense-making, which focuses on interpreting and understanding encountered information, thereby bridging the gap between locating information and deriving meaningful insights.

Another significant domain is decision-making (red cluster), intricately connected to information foraging. This area delves into the cognitive processes involved in utilizing information for decision-making purposes. Core concepts such as information processing, problem-solving, and learning feature prominently, highlighting the transformation of raw data into actionable knowledge. This cluster offers a wealth of psychological insights, examining the influence of attention, memory, and motivation on the effective processing and application of information.

Interwoven with these themes are studies on *visual attention* and *user interaction*. Keywords such as *eye-tracking* and *visual search* highlight the use of advanced technology to analyze how individuals visually navigate through information. These insights inform the design of user interfaces, ensuring alignment with natural tendencies to make information foraging as intuitive as possible. The keyword map also underscores the interdisciplinary nature of information foraging research. Concepts from cognitive psychology, behavioral research, and computer science converge, forming a comprehensive body of knowledge. For instance, foraging theory offers a theoretical framework derived from biology, while mathematical models provide quantitative tools to predict and optimize information-seeking behaviors.

The keyword map illustrates a dynamic field where research continually explores and refines methods for seeking, retrieving, and using information. This field acknowledges the complexity of human cognition and behaviour, aiming to develop systems that meet informational needs efficiently, intuitively, and effectively. The ultimate goal is to improve the ability to make informed decisions, manage knowledge, and navigate the expanding sea of information with ease and confidence.

All Keywords on IFT 1992-12023

Table 1 provides an overview of various keywords related to information foraging, categorized into distinct clusters. These clusters represent thematic groupings, each encompassing a range of related concepts. Cluster 1, the most prominent, includes key terms such as “human”, “humans”, and “decision making”, highlighting a strong focus on human behaviour and cognitive processes in information seeking. Notably, terms like “information seeking” and “decision making” have high frequencies and average publication years from 2014 to 2016, indicating a recent and substantial body of research. Cluster 2 is characterised by keywords like “information foraging” and “information foraging theory”, which dominate this cluster with significant link strengths and occurrences. This underscores the foundational role these concepts play within the broader research domain, with average publication years around 2013-2014, suggesting their ongoing prominence in the literature.

In Cluster 3, the focus shifts towards user interfaces and human-computer interaction, with key terms like “user interfaces” and “human engineering” standing out. These terms have substantial total link strengths and occurrences, with average publication years from 2008 to 2010, highlighting the historical development and ongoing relevance of user-centered design in information foraging. Cluster 4, which includes terms like “information retrieval” and “websites,” emphasises the technological and practical aspects of information seeking. Keywords such as “search engines” and “web browsers” also feature prominently here, reflecting the centrality of these tools in the process of information retrieval. The average publication years for these terms span from 2011 to 2012, indicating an established area of study that continues to evolve. Cluster 5 is marked by an interest in visualization and semantics, with keywords like “visualization” and “semantics” leading the cluster. This cluster also includes "sensemaking" and "exploratory search," which have significant occurrences and average publication years from 2012 to 2014, indicating a growing emphasis on how users interpret and interact with information visually.

Cluster 6 focuses on social aspects and information systems, with terms like "social networking (online)" and "information systems" having notable link strengths and occurrences. The average publication years for these terms range from 2012 to 2016, reflecting the increasing integration of social dimensions in information foraging research. Cluster 7 delves into information management and behavioural research, with "behavioural research" and "information use" being key terms. This cluster also highlights the role of "information sources" and "information seeking behaviours," with average publication years from 2013 to 2016, suggesting a focus on how users manage and utilise information.

Table 1: Overview of Keywords Associated with Information Foraging, Categorized into Distinct Clusters based on Thematic Groupings

No	Label for Terms	Cluster	Links	Total link strength	Occurrences
1	information foraging	2	161	279	293
2	information retrieval	4	117	68	68
3	information foraging theory	2	99	57	59
4	information seeking	1	94	34	34
5	behavioural research	7	86	29	29
6	semantics	5	83	21	22
7	websites	4	82	46	46
8	search engines	4	81	44	45
9	decision making	1	77	32	32
10	information scent	3	76	37	37
11	user interfaces	3	75	27	28
12	human	1	75	43	43
13	humans	1	74	41	41
14	visualization	5	72	32	32
15	social networking (online)	6	70	18	18
16	human engineering	3	70	33	33
17	article	1	70	28	28
18	human computer interaction	3	69	28	28
19	world wide web	3	69	32	32
10	web browsers	4	62	31	31
21	data mining	4	59	19	20
22	information analysis	3	59	19	19
23	information systems	6	58	21	21
24	information use	7	57	22	22
25	knowledge management	6	56	17	18
26	sensemaking	5	55	19	19
27	computation theory	2	55	23	23
28	foraging	1	55	16	18
29	algorithms	4	53	15	15
30	artificial intelligence	4	52	10	10

In respect of links, Table 1 also provides valuable insights into the relationships between various keywords through the "links" column, which indicates the number of connections each keyword has with others. When sorted in descending order, it reveals the most interconnected and central terms within the information foraging domain. At the top of the list is "information foraging," which stands out with a total of 161 links. This term's high connectivity underscores its pivotal role as a central concept in the study of how users seek and gather information. Closely related is "information retrieval," with 117 links, highlighting its significant relevance and numerous connections to other key topics in the field. "Information foraging theory" follows with 99 links, reinforcing the foundational nature of this theoretical framework within the broader discourse. The concept of "information seeking" also shows a strong presence with 94 links, reflecting its fundamental importance in understanding user behaviour in information foraging contexts.

Other highly linked terms include "behavioural research" (86 links) and "semantics" (83 links), indicating substantial interconnections with various other topics. The presence of the term "websites" (82 links), illustrates the essential role of web platforms in the information retrieval and foraging process. "Search engines" also feature prominently (81 links), emphasising their critical function as tools for accessing information. "Decision making" (77 links) shows significant connectivity, underlining its importance in the context of information foraging, where users constantly make choices based on available information. "Information scent," a concept related to the cues that guide users towards relevant information, has 76 links, highlighting its role in understanding how users navigate and search for information. The term "user interfaces" also stands out with 75 links, reflecting the centrality of interface design in facilitating effective information foraging. Other noteworthy terms with substantial links include "human" (75 links), "humans" (74 links), "visualization" (72 links), and "social networking (online)" (70 links), each demonstrating significant connectivity and relevance within the information foraging landscape.

This interconnectedness is further exemplified by terms like "human engineering" (70 links), "article" (70 links), and "human computer interaction" (69 links), which showcase the diverse and interdisciplinary nature of research in this area. Additionally, "world wide web" (69 links) and "web browsers" (62 links) highlight the critical role of the internet and web technologies in information foraging practices. In the context of practical applications, terms like "data mining" (59 links) and "information analysis" (59 links) illustrate the importance of analytical techniques in processing and interpreting large volumes of information. The terms "Information systems" (58 links) and "knowledge management" (56 links) reflect the organisational and management aspects of information foraging.

The "Total Link Strength" column in Table 1 provides an important perspective on the relationships and significance of various keywords in the field of information foraging. By analysing total link strength, insights emerge into the intensity and robustness of connections between keywords, reflecting the depth of research and collaboration in these areas. Leading the list is "information foraging", with the highest total link strength of 279, emphasising its central and influential position within the broader research landscape. This value illustrates a well-established network of connections with numerous key concepts in the field. Closely following is "information retrieval," with a total link strength of 68, underscoring its substantial impact and strong interconnections within the domain, highlighting its fundamental role in how users locate and access information. "Information foraging theory" also shows a substantial total link strength of 57, emphasising its foundational role and the extensive research connected to this theoretical framework. Similarly, "information seeking" has a notable total link strength of 34, indicating its essential place in understanding user behaviour and information search processes.

"Behavioural research" stands out with a total link strength of 29, demonstrating the importance of behavioural studies in the context of information foraging. This term's strong connections to other keywords reflect the interdisciplinary nature of the field, where insights from psychology and behaviour play a crucial role. “Semantics” appears with a total link strength of 21, highlighting its relevance in understanding the meaning and context of information. This term’s connections to other keywords indicate its role in enhancing information retrieval and processing. The term “websites” shows a total link strength of 46, underscoring the pivotal role of web platforms in the information foraging process. Similarly, “search engines” have a total link strength of 44, reflecting their critical function as tools for accessing and retrieving information.

“Decision making” features prominently with a total link strength of 32, highlighting its significance in the information foraging context, where users continuously make decisions based on available information. “Information scent” also shows a robust total link strength of 37, emphasising its role in guiding users towards relevant information through various cues. “User interfaces” stands out with a total link strength of 27, reflecting the importance of interface design in facilitating effective information foraging. Additionally, “human” and “humans” both have a total link strength of 43 and 41, respectively, indicating their centrality in the study of user behaviour and interactions. Other terms with substantial total link strength include “visualization” (32), “social networking (online)” (18), and “human engineering” (33), each demonstrating strong connections and relevance within the information foraging landscape. These terms highlight the diverse and interdisciplinary nature of the research, encompassing aspects of technology, behaviour, and social interaction. The terms “article” (28), “human computer interaction” (28), and “world wide web” (32) also show significant total link strength, underscoring the broad scope of research and the integration of various domains within the field of information foraging.

Examining the “Occurrences” column Table 1 provides a clear picture of the frequency with which each keyword appears, highlighting the most commonly researched and discussed topics within the field of information foraging. When sorted in descending order, the table reveals which concepts have garnered the most attention and focus in the literature. At the top of the list is “information foraging”, which has the highest number of occurrences (293 times). This reflects its central and pervasive role in the research landscape, indicating a substantial amount of study and discussion around this concept. Next is “information retrieval”, (68). This high frequency underscores the importance and relevance of information retrieval in the context of how users search for and access information.

“Information foraging theory” follows with 59 occurrences, emphasising its foundational status and the extensive research connected to this theoretical framework. Similarly, “information seeking” has 34 occurrences, highlighting its essential place in understanding user behaviour and search processes. “Behavioural research” appears 29 times, showcasing the importance of behavioural studies in the context of information foraging. This frequency reflects the interdisciplinary nature of the field, where insights from psychology and behaviour are crucial. “Semantics” shows 22 occurrences, indicating its relevance in understanding the meaning and context of information. This term’s frequency points to its role in enhancing information retrieval and processing. The term “websites” has 46 occurrences, underscoring the pivotal role of web platforms in the information foraging process. Similarly, “search engines” feature prominently with 45 occurrences, reflecting their critical function as tools for accessing and retrieving information.

“Decision making” shows up 32 times, highlighting its significance in the information foraging context, where users continuously make decisions based on available information. “Information scent” appears 37 times, emphasising its role in guiding users towards relevant information through various cues. “User interfaces” is mentioned 28 times, reflecting the importance of interface design in facilitating effective information foraging. Additionally, "human" and "humans" are frequent terms with 43 and 41 occurrences, respectively, indicating their centrality in the study of user behaviour and interactions. Other terms with notable occurrences include "visualization" (32), "social networking (online)" (18), and "human engineering" (33), each demonstrating strong connections and relevance within the information foraging landscape. These terms highlight the diverse and interdisciplinary nature of the research, encompassing aspects of technology, behaviour, and social interaction.

The terms "article" (28), "human computer interaction" (28), and "world wide web" (32) also show significant occurrences, underscoring the broad scope of research and the integration of various domains within the field of information foraging. Additionally, terms like "data mining" (20) and "information analysis" (19) illustrate the importance of analytical techniques in processing and interpreting large volumes of information. "Information systems" with 21 occurrences and "knowledge management" with 18 occurrences reflect the organizational and management aspects of information foraging.

Emerging Areas

To identify emerging themes in the field of information foraging, the data from Table 1 were analysed based on several key criteria. Keywords with more recent average publication years were emphasised, as these indicate newer research interests and trends, reflecting the latest developments within the field. These terms are likely to represent emerging areas of study and highlight current research directions. Contextual relevance was also a crucial consideration. Keywords aligning with prevailing technological and social trends were identified as emerging. For example, the growing influence of social media in daily life and the increasing importance of collaborative platforms such as Stack Overflow underscore the relevance of these keywords to contemporary research. These terms highlight the ongoing evolution of the information foraging field, reflecting its integration with contemporary digital environments and user behaviors. Table 2 provides the results alongside detailed explanations, offering insights into the emerging themes and their implications within the research domain.

DISCUSSION

The evolution and future directions of IFT research present a significant narrative over the past 32 years, from 1992 to 2023. IFT has experienced notable growth and diversification, underscoring a collaborative effort to advance the understanding of human information-seeking behaviour. Peter Pirolli emerges as the most prolific contributor, having co-developed foundational concepts with Stuart K. Card at Xerox PARC in the early 1990s. Pirolli & Card's (1999) seminal paper, "Information Foraging," introduced key concepts such as information scent and information patches, establishing a theoretical framework that catalysed subsequent research and firmly positioned IFT within the academic community. Other significant contributors include Margaret Burnett, Yacine Drias, Saeed Kuttal, Ross Bellamy, Bonnie E. John, and Daniel Piorkowski, who have collectively enriched the field with diverse insights.

The interdisciplinary nature of IFT is noteworthy; it has evolved from its cognitive psychology and HCI roots to influence areas such as information science, organisational behaviour, and machine learning (Bryant, 2014; Fok et al., 2024). Researchers have applied IFT principles to enhance web interfaces, search engines, and recommendation systems, aiming to facilitate efficient information retrieval (Diwanji et al., 2022; Briggs et al., 2022). The early 2000s marked a surge in empirical studies validating and refining IFT, confirming its predictions about user behaviour, such as the pursuit of information scents leading to high-yield patches (Fu & Pirolli, 2007). Pirolli's 2007 book, "Information Foraging Theory: Adaptive Interaction with Information", further solidified this theoretical framework and explored practical applications in technology design (Pirolli, 2007). The 2010s and beyond have seen IFT adapt to new technological contexts, such as mobile and ubiquitous computing, the influence of social networks, and the integration of machine learning for predicting and enhancing information-seeking behaviours (Illingworth & Thomas, 2022; Diwanji et al., 2022). These developments highlight IFT's ongoing relevance and potential for further exploration.

Table 2: Emerging Themes on Information Foraging Research

No	Themes (Recent Publication)	Explanation
1	Human Experiment (2020)	This keyword indicates a recent surge in empirical studies focusing on human behaviour in information foraging contexts, reflecting a contemporary interest in understanding real-world applications and user interactions.
2	Foraging Theory (2020.8)	The recent focus on foraging theory suggests ongoing theoretical development and refinement, pointing to its importance in guiding new research and applications.
3	Stack Overflow (2020.8)	Emphasizing a specific platform, this keyword highlights the study of information foraging in online technical communities, relevant to the growing field of social and collaborative information behaviour.
4	Cognitive Loads (2019)	The recent interest in cognitive loads reflects a focus on the mental efforts involved in information foraging, relevant to designing more efficient and user-friendly information systems.
5	Uncertainty (2018.833)	This keyword underscores the importance of understanding how users cope with uncertain or incomplete information, a crucial aspect of effective information foraging.
6	Classification (of information 2018.4)	The focus on how information is categorised and structured indicates emerging research aimed at improving information retrieval and foraging efficiency.
7	Open Source Software (2018)	This keyword suggests an increasing interest in how open source communities engage in information foraging, relevant to collaborative and community-driven information behaviour.
8	Virtual Reality (2017.8)	Reflecting new technological advancements, the study of information foraging in virtual reality environments indicates an emerging intersection of information science and immersive technologies.
9	Specific Information (2016.6)	The focus on specific information types points to research aimed at understanding how users target and retrieve particular information, highlighting precision in information foraging
10	Big Data (2016.8)	The inclusion of big data as an emerging theme indicates a growing interest in how large datasets are navigated and utilised in information foraging, relevant to modern data-driven environments.

The annual number of publications on information foraging from 1992 to 2023 reveals key trends. After minimal activity in the early 1990s, with publications near zero (Fidel et al., 2004), publications gradually increased from 2000 to 2006, peaking around 2012 with about 35 publications, signaling growing academic interest (Franceschet, 2010a). A decline occurred from 2013 to 2016, with publications falling to 20-30, suggesting a phase of consolidation as the initial excitement subsided (Bryant, 2014). This downward trend continued until 2020, when publications dropped to around 5, possibly indicating a shift to more specialized research. However, by 2022, a slight resurgence occurred, suggesting renewed interest or new developments in the field (Fok et al., 2024).

The publication landscape is diverse, dominated by conference papers, totaling around 250, indicating that information foraging is actively discussed at conferences where researchers share their latest findings (Franceschet, 2010b). Following conference papers, journal articles comprise about 150 publications, emphasizing peer-reviewed research efforts. Review papers, numbering around 30, highlight the accumulation of knowledge that warrants good summaries, guiding future research directions (Bawden & Robinson, 2009). Despite being fewer, conference reviews (approximately 10) document key discussions and outcomes from major events, while books and book chapters (around 5 each) suggest deeper explorations into the subject. Data papers are rare, with just about 1 publication, reflecting a limited but present effort toward open data collaboration within the community (Hutchins et al., 2019).

The subject distribution further underscores the interdisciplinary nature of information foraging research. Computer science dominates with nearly 400 documents, indicating the discipline's relevance in studying algorithms and data retrieval systems (Diwanji et al., 2022; Bryant, 2014). The social sciences, engineering, and psychology each contribute around 50 to 100 documents, focusing on user interactions and cognitive processes related to information seeking (Barack et al., 2023). Neuroscience and medicine have fewer contributions (approximately 20 to 30 each), exploring the neural mechanisms of information processing (Hattersley et al., 2022). The visualization of keywords in the IFT literature from 1992 to 2023 illustrates a dynamic research landscape (Fok et al., 2024). At its core is the theme of information foraging, applied to human behaviour and navigation through vast digital information spaces. Related concepts such as navigation and empirical studies reflect the importance of user interactions with information systems. HCI emerges as a critical area, examining how users engage with digital interfaces to enhance information retrieval efficiency (Fu & Pirolli, 2007; Briggs et al., 2022).

Clusters of keywords reveal thematic groupings. For instance, Cluster 1 focuses on human behaviour and cognitive processes in information seeking, while Cluster 2 emphasizes foundational concepts of information foraging (Fidel et al., 2004; Charnov, 1976). Cluster 3 addresses user interfaces and HCI, and Cluster 4 concentrates on technological aspects like information retrieval and web browsing (Choo et al., 2000). Cluster 5 highlights visualization and semantics, indicating the growing emphasis on how users interpret and interact with information (Kuznetsov et al., 2022). Social dimensions appear in Cluster 6, and Cluster 7 centres on information management and user behaviour (Chang & Rice, 1993).

Emerging themes in IFT research indicate new interests, including contemporary focuses on empirical studies, theoretical developments, and the study of information foraging in online communities like Stack Overflow (Diwanji et al., 2022). Keywords such as “cognitive loads” and “uncertainty” suggest that researchers are increasingly examining the mental challenges users face during information foraging (Illingworth & Thomas, 2022). The emergence of “virtual reality” reflects an intersection with immersive technologies, while “big data” highlights a growing interest in navigating large datasets (Fok et al., 2024). These evolving themes indicate ongoing exploration and diversification within the field of information foraging.

CONCLUSIONS

This study demonstrates that IFT has become a robust, interdisciplinary framework, theoretically sound and practically relevant, providing concrete guidance for optimizing information systems. Its ability to incorporate cognitive, ecological, and biological insights, along with its application in real-world technology design, marks it as a well-developed and highly applicable paradigm in understanding and enhancing information-seeking behaviours. As research fields mature, foundational concepts become well-established, often leading to a slowdown in groundbreaking new research. Researchers focus on refining existing theories rather than introducing novel concepts. The interdisciplinary nature of IFT means its concepts are increasingly integrated into other disciplines, such as cognitive science, HCI, and behavioural economics, which can diffuse research efforts across multiple fields. Technological advancements and shifts in social behaviours influence research trajectories, drawing attention to contemporary phenomena like mobile computing, social media platforms, and big data analytics.

Funding and academic trends prioritise research areas perceived as urgent or impactful, such as cybersecurity, privacy, and artificial intelligence, potentially overshadowing other areas. Academic pressures and publication trends play a significant role, with areas promising innovative breakthroughs or high citation potential attracting more resources and attention. Practical applications in fields like user experience (UX) and design have become standard practices, leading to a shift towards application-driven research over theoretical exploration. IFT is most influential within specific disciplines such as information science, HCI, and cognitive psychology, providing foundational insights into user behaviour and optimizing information systems. However, outside these specialised areas, its recognition may be limited due to its complex and specialised nature. Technological and social changes further influence research trends, drawing researchers to explore contemporary phenomena that might not align directly with traditional paradigms like IFT.

Despite these factors, IFT remains a significant and valuable framework within its core domains, providing crucial insights into optimizing web interfaces, improving retrieval cues, and understanding user heuristics in information-seeking behaviours. Its application in real-world technology design demonstrates its practical relevance and ongoing impact. While it may not dominate broader academic discourse, IFT continues to inform and enhance our understanding of information behaviour and system design, cementing its place as an essential theory within information science.

The evolution of IFT has significant practical implications for the design and enhancement of digital interfaces, search engines, and recommendation systems. By applying IFT principles, designers can create user-friendly environments that facilitate efficient information retrieval, thereby improving user engagement and satisfaction. The insights gained from empirical studies that validate IFT predictions regarding user behaviour can inform the development of more intuitive navigation systems that align with users' cognitive processes, ultimately enhancing the overall user experience in information-rich contexts.

The ongoing diversification of IFT presents numerous opportunities for further research. Emerging themes such as the impact of cognitive load and uncertainty on information-seeking behaviour warrant deeper investigation, particularly in the context of online communities and immersive technologies like virtual reality. Additionally, exploring the intersection of IFT with machine learning and big data could yield valuable insights into predicting and enhancing information-seeking behaviours across various digital platforms. Future research could also focus on the application of IFT principles in novel contexts, such as social media or mobile computing, to expand the theoretical framework and its practical applications.

Despite the progress made in IFT research, several limitations persist. The declining publication trends from 2017 to 2022 suggest potential issues with sustained interest or engagement within the field, possibly indicating a need for renewed focus and innovation in research topics. Furthermore, while the interdisciplinary nature of IFT is notable, the predominance of publications in Computer science may limit perspectives from other fields, such as psychology and social sciences, which are crucial for understanding the complexities of human information-seeking behaviour. Lastly, the relatively small number of empirical studies on newer themes, such as big data and virtual reality, indicates a gap in understanding how these contemporary challenges affect users' information foraging processes.

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CONFLICTS OF INTEREST

The authors have no relevant competing interests to declare pertaining to the content of this article.

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