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Information shaping

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Abstract

In this article, I explore the relationships between how humans have evolved to interact with the material world and how we interact with our information worlds. I argue that shaping processes, exemplified by how early humans created stone tools, are core ways to interact with the world that are appropriated to interact with information to create information solutions. To test these claims, I examine existing studies of information use from a shaping perspective. I finish by discussing how this evolutionary perspective to information use can benefit discussions of information behavior.

1 | INTRODUCTION

Humans use information in many complex and innovative ways. No other species seem to think about information in the way that humans do, nor do they spend so much time organizing, selecting, storing, sharing, judging, and creating information as humans do. Information has profound implications on almost every aspect of our human lives. At the biological level, the large brains necessary for our increased use of information mean that humans have particularly difficult births, ones associated with increased risk of maternal and fetal mortality or injury (Burton et al., 2015) while at the global level, the ways in which we utilize information is crucial in responses to major crises (Piltch-Loeb et al., 2021).

Many authors have written about our information practices (e.g., Lea French & Williamson, 2016; McKenzie, 2003; Savolainen, 1995), the socially constructed and supported ways of dealing with information. Information practices are preserved within societies and form a repertoire of information interactions, often presented as socially preferred ways of interacting with the world. What is less well understood are the underlying principles that explain how these information practices come into being and what areas of theory are best placed to help us understand how they arise.

Several authors have identified evolution as providing a fruitful theoretical basis for investigating information behaviors (e.g., Bates, 2005; Pirolli & Card, 1999; Spink, 2010). This has led to theories that suggest that our human information behaviors are more advanced forms of those abilities possessed by simpler ancestor species (Bates, 2005; Madden, 2004), theories that our information behaviors are a form of behavioral plasticity enabled by cognitive apparatus that have evolved to utilize information (Spink, 2010), and theories that suggest that behaviors that evolved for one purpose can be adapted toward dealing with information, the classic example being Information Foraging Theory which explains how humans search for and assess information as being directly based on skills evolved to search for and assess food sources (Pirolli & Card, 1999).

This article examines a different line of evolutionary explanation and proposes that shaping processes, fundamental ways of interacting with the physical world, form the basis of how we interact with and use information.[1] These shaping processes provide the ability to transform reality into a different form, one that is more useful for current needs and goals. This perspective of information shaping provides explanatory power in understanding how we interact with information and how we develop tools to work with information.

I start by briefly outlining some of the main theoretical contributions to information behavior from evolutionary theory. Then I shall describe shaping processes and how they are adapted to information use, then demonstrate through cases studies how shaping lies behind many areas of information use. Finally, I shall provide some implications of this proposal and outline future directions.

2 | EVOLUTIONARY APPROACHES TO INFORMATION SCIENCE

In this section, I present a brief outline of the main evolutionary perspectives to information behavior, in roughly chronological order: Pirolli's development of Information Foraging Theory, Bates' evolutionary characterization of information, and Spink's evolutionary account of the development of information behavior.

2.1 | Pirolli and information foraging theory

The most developed evolutionary theory in Information Science is Information Foraging Theory, led by Pirolli and colleagues for nearly three decades (Pirolli & Card, 1995, 1999). The core hypothesis of Information Foraging is that, where possible, humans will adapt their information seeking to changes in the information environment with the goal of maximizing information gain against the cost of obtaining that information.

Based on the highly influential theory of optimal foraging, Information Foraging proposes that the way we make decisions during an information search is based on the skills we have evolved to forage for food. Two aspects of Information Foraging have been particularly persuasive. The first is that we make use of cues in our environment to locate useful sources of relevant information. Like animals using sounds, smells, and other traces to locate prey and make choices between one possible food source and another, we use cues from our proximal information environments, such as images, weblinks, and textual summaries, to make choices about where to navigate, how to adapt our information search strategy, and to predict where the most useful information may be found. This has led to many studies of how we construct information environments to aid this decision-making and to many studies of how people interact within such environments.

Second, the proposal that Information Foraging, like food-foraging, can be modeled using cost–benefit analyses has led to the development of sophisticated models of search behavior, many of which aim to predict how people will behave as their information environment changes.[2] The major focus in Information Foraging Theory therefore is on obtaining information rather than what we do with it once we have it.

2.2 | Bates and information

In 1989 Bates introduced her famous berry-picking model in which she characterized the search process as one that was analogous to the process of picking berries from fruit bushes (Bates, 1989). She does not directly frame this as a process with an evolutionary basis—the word evolve is used in the context of the search rather than why the behavior has arisen—however, the analogy clearly points to food seeking behaviors being adapted to information seeking. While there are clear similarities to Information Foraging Theory, there are also distinctive features of both approaches (Savolainen, 2018).

In later works, she examines information itself from an evolutionary perspective (Bates, 2005). Sketching a much bigger argument, she focusses on the ability to observe, use, and assign meaning and significance to patterns within nature, particularly emergent patterns. Being able to detect emergent patterns helps plan but also helps abstraction, for example, abstracting changes in daily weather to seasonal patterns, and therefore maximizes information storage. Being able to better detect and use these patterns, and reason about their underlying organization, confers advantage to animals in terms of finding food, selecting mates, and providing protection against other animals and environmental dangers. This promotes the evolution of sophisticated cognitive structures for dealing with and using such patterns.

Higher animals can experiment with the world to learn more about it and humans in particular act in planned ways to learn about the world around them. This includes learning more about the world that they cannot directly observe (Bates, 2005) through new technology. They also change the world, and therefore change the environment in which evolution is having an effect (Bates, 2018).

Bates' vision then goes from the ability to perceive stimuli from the external world, detecting patterns and importantly, differences in patterns, and from this to higher-level information storage and use. That is, from passive recipients of changes in our environments to active, engaging, meaning-determining agents withing socio-cultural grouping. This vision serves as a proto-paradigm to investigate the development of information itself (Bates, 2022).

2.3 | Spink and information behavior

In her major work on information behavior as an evolved series of responses to the world, Spink (2010) squarely places information as a human activity: "*information*

behavior is a crucial everyday human activity for all humans since the early days of human evolution" (p. vii) and she clearly implies homo sapiens rather than other human species when talking of humans. She views information behavior as coming from the drive to both control one's proximal environment and to dominate other species, especially those that act as competitors for resources. This is classic evolutionary theory.

She describes information behavior as an instinctive feature of human interaction with the world and that our human ability to coordinate behaviors such as language, decision making, planning, and abstract thinking provided the medium from which information abilities could develop. Information behavior not only developed alongside other human socio-cognitive abilities such as hunting and gathering but enabled humans to be better at these activities: "*[s]uccessful hunting and gathering requires information behavior abilities, including the ability to collect, store and use information about the animals hunted, the plants gathered, the timing of the seasons, changes in weather and temperature, and passing information to future generations*" (Spink, 2010, p. 19). Being able to seek, organize, and use information provided ecological advantages and therefore are developed and selected through generations.

Although she does not use the term itself, predictability is clearly an important benefit of information behavior in her account. The collective sharing of information and information solutions enables greater predictability about the world and ways of acting with it. It also provides ways to do things differently; as she describes, increased cognitive abilities allows for novelty and innovation in how we do things and explains why we may behave differently when circumstances demand.

Her broad framework sets out an ambitious roadmap for investigating how generalized cognitive abilities such as language, instinct, and capacities for innovation and adaptation translate into information behaviors such as organizing, searching, and storing information. What it does not do is provide an account of how we use information.

2.4 | Summary

These three bodies of work all argue to powerful evolutionary forces underpinning how we interact with information. Bates' primary focus is on information and the evolutionary advantage to being able to use our sensory and perceptual inputs in complex and innovative ways and hence a drive toward more sophisticated cognitive structures for representing and reasoning about these inputs. Spink largely follows this line of thought but with a focus on higher-level cognitive abilities, modular cognitive functions, and a strong emphasis on information behavior as a conscious human activity. Pirolli et al. have a focus on obtaining information and the evolutionary advantage of maximizing gain while minimizing effort in information spaces.

What these accounts lack though is a more general theory to explain how we *use* information. In this article, I propose a new information theory that provides such an account. This account straddles the boundary of evolved characteristics and cultural responses: what evolutionary advantages nature gives us and what our environment encourages us to do with these advantages.

3 | SHAPING

In this section, I briefly outline how humans moved from interacting with the world using hands to interacting using tools and the characteristic ways in which they developed these tools, known as shaping processes. These shaping processes are exemplars of how humans solve problems in the natural world, ones that are stored within our cultural repertoire through social learning. This sets the scene for the argument in the following section that these shaping processes are the foundations for how we use information to solve problems.

3.1 | Interacting with the natural world

All organisms exist within a three-dimensional world and interact with this world. Simple organisms may only passively respond to their environment whereas more complex organisms can change their environment to fulfill goals such as mating, feeding, and gaining protection: birds build nests, dogs bury bones, rabbits create warrens, and so forth. Being able to reshape the physical world gives advantage over simply reacting to it and evolved physiological adaptations such as beaks, paws, teeth, claws, and opposable thumbs allow living organisms to interact more successfully with the world to achieve their goals.

Bipedalism is seen as a crucial development for humans as it frees hands to become different to feet—they are not just two sets of paws—and for hands to become general purpose ways of interacting with the world: they can hold, grasp, separate, join, rub, sort, group, mold, push, press, and pull. These generic ways of interacting with the world form a toolkit of tactile devices for changing the world. As most people have two hands, they can be used to compare objects for weight, firmness, ripeness, and be used for simultaneous activities such as holding an object with one hand and manipulating it with the other. They become primary ways to change the world and, along with vision, to learn about the world and its properties.

Physical gestures are linked to specialized brain regions dedicated to the manipulation of the hands forming a cognitive-physical feedback loop. This implies that physical manipulation of the world is innate, that these are natural ways to interact with the world. Tasks that involve the development of skills, such as mathematical thinking or additional language development, can lead to increases in the amount or density of gray matter in the brain during an individual's lifetime (Aydin et al., 2007; Woollett & Maguire, 2009). This includes tasks such as musicianship which involve the integration of sensory and motor information (Gaser & Schlaug, 2003). Therefore, we are gifted at birth with the ability to learn how to interact physically with the world and, as we interact, our brain continue to change in response to how we are physically interacting with the world (Gaser & Schlaug, 2003).

3.2 | Shaping

While we can use hands to change external reality, we can also do this using other objects. Animals often employ objects to help with their goals, for exampling using stones to break open foodstuffs. Such behaviors led to the famous claim that the ancient Greek playwright Aeschylus was killed when an eagle, mistaking his bald head for a rock, dropped a tortoise on his head to smash open the tortoise's shell. Human species have gone further by changing material into new forms—tools—to interact more successfully and strategically with the physical world. This is a form of outsourcing in which we move a function onto an external entity and thereby extending our natural capabilities. That is, we can *create* a range of abilities, such as spearing, cutting, scraping, that would otherwise only be possible if we evolved specialist anatomical structures. That hands are general purpose ways of interacting is significant as most other animals have evolved specialist ways to interact with the world which allows for a narrower range of goals. Humans instead use hands to create and hold tools, expanding our biological capacities with technology. As Bates and others have argued, we must consider humans *and* what they create, their extended phenotype, as part of what it means to study humans (Bates, 2018). The way in which we create these tools is indicative of how we solve problems in the natural world and is best exemplified by the development of stone tools.

The first evidence of stone tools produced by humans was about 3.3 million years ago (Harmand et al., 2015). The most likely pattern of development in these tools was using existing rock fragments for basic actions such as cutting, followed by working stones into more useful shapes, for example, by sharpening raw edges, and then a movement toward reshaping whole rocks into distinct forms such as axes. By this stage, humans were creating objects that were unrecognizable from their original form. This process is often referred to as *shaping*: reworking parts of the world into a new form. Stone tools, being made of durable material, are more easily preserved than other materials and offer the best evidence of shaping processes. However, the process of creating stone tools illustrates general principles of interacting with natural environments and creating solutions to problems that arise within those environments.

First, that the process seems to be one of *local optimization*. Tool production works on a process of making the best of available materials. While early humans seemed to spend effort getting the best materials for their tools (Boaretto et al., 2009), they had to work within localized spaces so the tools are compromises between what was needed and what could be achieved. There is evidence that early humans made "*well balanced decision procedures*" (p. 10) about materials, their uses, and how much effort to expend in gaining materials for tools (Boaretto et al., 2009).

Second, solutions range from *generalized* to *specialized*: tools fall into basic classes such as cutters, scrapers, hammers, and so forth, but they can also be specialized for different cutting, scraping, or hammering purposes. This reflects an interplay between a task and the materials available so hammering a bone to extract its marrow may require a different tool than hammering a stone to create a new ax. Specialized tools may look very different to each other, while being still broadly recognizable as belonging to the same class of objects, and be entirely unrelated to the shape of the original material (Muller et al., 2022). Pirolli et al. noted that that we expect designs to evolve if they are successful: we start with broad general solutions, learn from them about their properties in use and then adapt the solutions to more specialized forms (Pirolli & Card, 1999). This requires the ability to conceptualize a class of solutions, and the processes to create these solutions, rather than just create solutions to each problem situation.

Third, shaping solutions require *experimentation*. Trial-and-error is a major source of innovation in human and non-human primates (Paolo & Vincenzo, 2018). Experimentation is a highly characteristic behavior of humans: we probe, test, and interact with the world to learn its properties and how it reacts to our actions. As Hertzum observes, experimentation is useful to *create* new information in situations where we have imperfect information on how to act: experimentation provides new information that helps resolve the situation from within the situation (Hertzum, 2023). Shaping processes emphasis experimentation because solutions arise through interaction with the raw material so the final solution is not known from the start but rather emerges, often in a trial-

and-error fashion (Lockman, 2005). Even if good solutions are the basis of future solutions, we do not stick to just one solution, often we work with multiple and competing ways of solving problems over extended periods of time (Lockman, 2005). Experimentation allows us to think about alternatives, try them out, and develop skills. Experimentation also allows us to use, and therefore test, solutions as they move toward final forms, assessing them in action against their final purpose.

Fourth, shaping involves *iteration* and *approximation*. Tool shaping processes go from bolder, coarser initial cuts by which large flakes are removed from stone bases then, as the shape of the final artifact becomes clearer, smaller pieces are removed. This means that bigger gestures are more typical of early stages, smaller refinements more typical of later stages. In the later stages, the predictability of the shaping gestures is better whereas in the early stages the larger gestures used are less predictable in their effect and the shaper needs to spend more time thinking about their actions (Muller et al., 2022).

Finally, shaping is *perceptual*. Our physical actions while shaping form part of a feedback loop: we act upon the world, perceive changes based on our actions, interpret, and evaluate these changes, then decide how to act next and therefore perception and action blend in experimentation. Through shaping we are constantly perceiving physical differences in the material we are changing—its weight, sharpness, its "feel" in our hands—and testing it against its final purpose. That is, "*cognition is enactive, constituted by the dynamic interactivity between brains, bodies, and material environments*" (Bruner et al., 2018, p. 302).

Therefore, shaping in the form of tool development is a way of transforming material in one form into another form, one that is more suitable for a current problem. This interaction between brains and material artifacts "*through the interface of hands and eyes fundamentally underpins and pervades the evolutionary history of our species*" (Bruner et al., 2018, p. 310) and it exemplifies a way of physically acting upon the world that works on gradual, iterative, broad to specific solutions with a strong emphasis on physicality and perceptual-cognitive feedback loops. Although tool development is the classic form of shaping, similar processes underlying other human activities such as cooking: we tend to work with ingredients to hand or obtained locally, start with bigger gestures such as chopping, mixing, and so forth with fine-grained adjustments coming later, it is highly perceptual, encourages experimentation, and basic recipes have been converted into many specialized forms. Aesthetic activities such as home decoration or gardening also start with broad, coarser actions followed by refinement, they often involve experimentation based on basic patterns, and involve enacted cognition as defined above.

The previous section emphasized the nature of shaping processes and their basis in the way humans interact with a physical world. As humans are social animals, our social environments encourage certain ways of thinking about our environment and how to interact with it and this culture emphasizes the preservation of successful solutions.

3.3 | Social learning and cumulative culture

Culture is often defined as the behaviors that are acquired and transmitted (at least partly) through some form of social learning (Reindl et al., 2018). Cumulative culture is the process by which behaviors and innovations are incorporated into a groups' existing repertoire of skills and knowledge, allowing for the development of more complex ways of interacting in their environment (Legare, 2017). This allows individuals to access solutions that they themselves could not have innovated (Reindl et al., 2018; Tennie et al., 2020). The tools created by humans, and the passing on of this cultural knowledge, allowed humans to engage in what is known as "niche construction" in which organisms change their environment which in turn affects natural selection (Bates, 2018).

Cumulative cultures allow for the development of variants of existing procedures to become more efficient or complex (Watson et al., 2018). These solutions are often highly local with limited variability within groups and higher variation between groups (Haslam et al., 2018). In other words, local communities have their own ways of doing things that are preserved, adapted, and become recognizable traits of the communities. This is also true of primates but the gradual accrual, preservation, and development of traditional ways of doing things seems to be characteristic of humans (Renner & Zawidzki, 2018). New cultural traits may also develop through combinations of existing traits leading to "*exponential rates of cultural accumulation*" (Creanza et al., 2017, p. 7783).

Successful innovation has to co-occur with social learning otherwise innovations are not transferred and do not accumulate (Paolo & Vincenzo, 2018). Social learning can range from simple observation to more sophisticated phenomena such as teaching and reproduction (Watson et al., 2018) and is particularly important as many innovations require engaging in "*sequences of multiple, precisely executed steps, the roles of which are opaque relative to the ultimate goal*" (Renner & Zawidzki, 2018, p. 252) and therefore would otherwise rely on individual innovation which is unlikely to reach the same solution.

A key feature of social learning is imitation. High fidelity imitation has been argued as the reason that some

human tools, such as hand-axes, have been so consistent across human culture (Shipton & Clarkson, 2015) and that humans have high copying fidelity because humans, unlike primates, pay attention to the sequences of actions in tool production and not just the outcome (De Petrillo et al., 2018).

Imitation seems to be genetically preferred: those who are more inclined to imitate when children are more successful as adults as they have a greater store of knowledge and skills (Paolo & Vincenzo, 2018) and those who are more inclined to repetitively imitate (practice) as children are those who gain basic skills that help them become competent innovators later in life (Paolo & Vincenzo, 2018). What seems to be particularly characteristic of humans, and key to their success in tool production, is *over*-imitation. Over-imitation seems unique to humans: we take a procedure (a behavioral chain) and turn it into an outcome which can be adapted, experimented with, and innovated so that we do not only seek to replicate the procedure but we treat it as a potential way of obtaining a goal which can be varied (Paolo & Vincenzo, 2018). (Over-)imitation provides a structure for innovation as most innovation, including errors, happens within successful structures for conducting a task and therefore most innovation takes place with generally accepted and understood ways of doing things.

Being competent at making tools changed the environment of early humans as this ability made the environment more stable and predictable (Paolo & Vincenzo, 2018). As humans became better at the processes of making tools, then activities such as teaching and learning become important (Paolo & Vincenzo, 2018) and it has been argued that teaching itself became preferred through evolution (Pargeter et al., 2020) to enable greater preservation of culturally accumulated skills. This transformation into a shared social organizational activity meant that "*procedure, demonstrator, physical objects and spaces in the world become more and more interconnected, making it actually impossible for them to be separated again*" (Paolo & Vincenzo, 2018, p. 278).

4 | INFORMATION SHAPING

The argument behind evolution is that organisms continually develop, both to deal with changes in their natural environment and to make better use of their environment. This means that evolution is not a process toward some ideal end point but rather a series of actions, reactions and adjustments based on existing capabilities.

Our existing information behaviors are a mixture of innate behaviors, such as those described by Bates (2005), and those that are adaptations to our environment based on innate behaviors. Information behaviors such as reading and writing are not dealt with by specialist brain regions evolved for those purposes; for most of human history, most people could not read or write so there was no genetic advantage to these behaviors. What we are doing in the case of reading and writing are exploiting our innate abilities for vision and language and using them for a new purpose.

Much of the information work in which we now engage is very new in historical terms. When dealing with modern complex information environments and information tasks, we do not have innate ways to resolve these problems, instead we co-opt existing abilities to new challenges. The shaping processes described above are an example of innate capabilities. They are a class of behaviors that predate modern humanity and represent general ways of interacting with the world to change parts of the world into a different form. This article proposes that these innate abilities form the basis of how we approach the much more modern task of information use.

Specifically, the two central arguments made in this article are that:

1. *Shaping processes underpin much of our information use*. That is, the way we use information for many information problems is based on co-opting of the same skills we use to shape physical material into solutions, as exemplified by the above description of how we shape tools. Formally these can be seen as a form of behavioral plasticity by which existing skills are called upon to meet new challenges.

Here the argument is that, as information problems became more numerous and complex, we needed ways to use information to create what might be characterized as information solutions (writing a report, choosing a mortgage, creating a plan to remodel a house, etc.). We do not have pre-compiled approaches for such tasks. Rather they are seen as ill-defined problems that require the acquisition of information from external sources, application of knowledge to define goals, decisions on courses of action, the development of heuristics, and assessment of developing solutions (Pirolli & Card, 1999). Sometimes the problem is more complex with unclear inputs, processes, or even clear ideas of the end-goals (Byström & Järvelin, 1995). Tool production requires constant correction due to the variability of material, we can also suggest this as a characteristic of information: the material we have is variable and, even though the function of the final form may be known (a report, a decision, etc.), how we transform the information available into the required final form is not known.

Historically, the way humans have created solutions is through shaping: transforming material in one form into another form, one that is more suitable for a current problem via gradual, iterative, broad to specific solutions with a strong emphasis on physicality and perceptual-cognitive feedback loops. This is a natural and widely used, almost default, way of interacting with the physical world. Therefore, when encountering new material—information—then it seems natural that the same how-to skills are being deployed here.

2. *Social learning of shaping solutions is the basis of information practices.* The description of social learning, above, illustrates how successful solutions become part of the repertoire of a group. Cultural accumulation encourages the storage of successful solutions as the basis for future solutions and as the site of innovation. Therefore, individual successes can become incorporated into the natural ways of doing things that act as the assembled skills of a group of people. These can develop into local variations that act as devices of social cohesion: many groups of humans developed stone axes but they varied the handles, the decoration, and so forth and therefore the associated practices of developing these tools (Weedman, 2006). Others have argued that the consistency in the shape of hand ax within local communities is a consequence of the emergent shapes produced by individuals being constrained by the imposition of social norms that are "*negotiated, understood, and adhered to at the wider group level*" (Hutchence & Scott, 2021, p. 675).

Therefore, the individual shaping activities benefit from and are constrained by the practices of the group: they benefit from having established models of solutions, (perhaps) teaching of these solutions, and they are steered by those solutions at the same time. This is like practice arguments for our information work: we operate within socially constructed ways of creating information solutions, these are embedded within other social practices, they represent regular, repeated ways of operating, and they have meaning and values within the community (Savolainen, 2007).

These practices can manifest in tangible forms as well. Yates and Orlikowski, for example, saw social practices as key to the development of genres: "*genres are social institutions that are produced, reproduced, or modified when human agents draw on genre rules to engage in organizational communication*" (Yates & Orlikowski, 1992, p. 305) noting that genres "*both shape and are shaped by individuals' communicative actions*" (Yates & Orlikowski, 1992, p. 300) highlighting the bidirectional way in which existing ways of creating solutions influence new solutions and that individuals contribute to the development of these ways of creating solutions.

Figure 1 summarizes the ideas behind information shaping: our evolving cumulative information culture (our stock of information practices, information tools, and information solutions) creates a cultural information repertoire. Individuals access this collection of community knowledge through processes of social learning; in turn, social learning expands and develops this cumulative information culture as the community takes on new or modified solutions developed by individual members of the community. Individuals and groups engage in individual shaping experiences when they develop solutions to information problems and the approach they take is characterized by the five principles described above.

5 | EXAMPLES OF SHAPING

There is unlikely to be direct evidence to support the proposition that shaping tools is the basis of how we shape information, the evidence available from history is rarely that clear and precise. However, what we can do is examine existing evidence on how we solve information tasks and see how they map onto these information shaping ideas.

In the sections below, I present some illustrative examples. There is a paucity of studies that describe information use over time, but I have tried here to find quite different examples of the ones that are available. Two (Kuhlthau's Information Search Process and Vakkari's work on task-based searching) are classically seen as information seeking studies but, in both the participants are using information, while interacting with it, to shape an overall understanding of the information required for a task. Ruble is a very different type of information use in which information is used in the process of identity development, and finally, Allard and Caidi is used to study a situation in which information is being used to understand how to live in a new location.

5.1 | Kuhlthau and the Information Search Process

Kuhlthau's Information Search Process (ISP) is one of Information Science's landmark studies, describing the stages through which students proceed when engaged in a learning task, specifically writing a research paper over the course of an academic semester (Kuhlthau, 1993). In her studies, Kuhlthau uncovered six phases: *initiation* in which the students were focused on understanding the

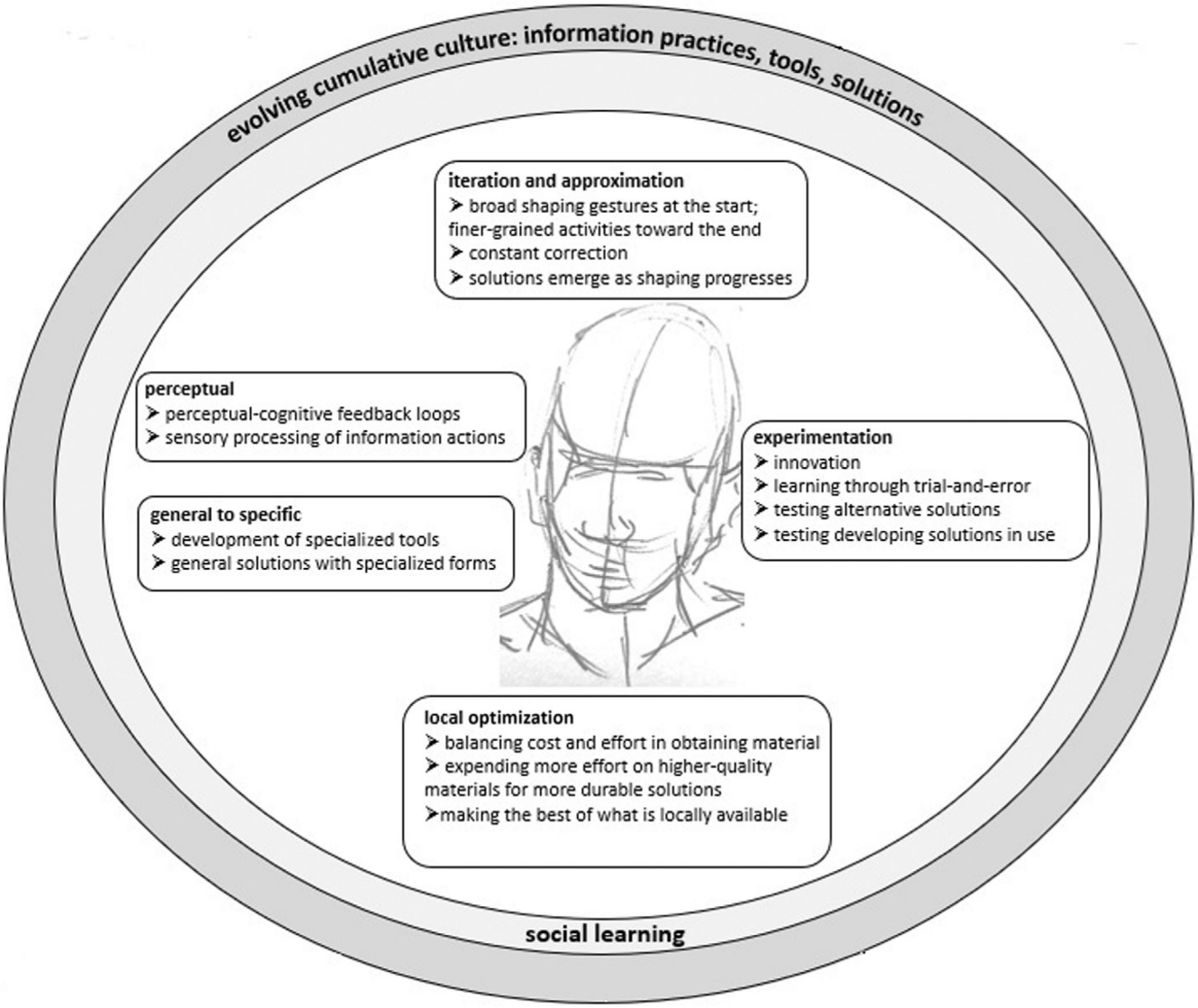

FIGURE 1 Information shaping principles.

task and how it relates to previous knowledge, *selection* in which they decided on a general topical area, *exploration* in which they investigated information resources to find a specific focus, *formulation* in which they choose a focus, *collection* when they refine the focus and gather information to support it, and *presentation* when they complete the task (Kuhlthau, 1993).

We can read Kuhlthau's ISP through the principles of information shaping. The focus on making the best of available material, that of *local optimization*, is evident in the ISP. Early stages of the ISP are about ascertaining what material is available (initiation), doing superficial rather than deep reading to become informed (initiation and selection), using available material to consider topics (selection). These are broad orientation-focused activities. Later stages of the ISP involve more considered, value-led judgments on material to obtain relevant information (exploration), pertinent information (collection), and seeking information for specific purposes such as refining the focus (collection). Overall, there is a process of working out what information is available and then how it can be used with more effort being expended on material that may be of more use to the task.

Kuhlthau observed that the more often the students completed similar tasks, then the more they became aware of the ISP as a generic process with distinct phases, rather than just a specific set of activities to pass a specific assignment. Like the principle of *specialization* in shaping, students moved from creating a single solution to conceptualizing a class of solutions and the processes to creation these solutions, as Kuhlthau noted "*They also showed a sense of ownership in the process and the strategies they used to work through the stages, referring to 'my process' and relating 'this is the way I do it'*" (Kuhlthau, 1993, p. 71).

Kuhlthau clearly describes the *experimentation* involved in the ISP. We see this in the selection phases where students were weighing topics against various criteria and predicting outcomes. Later, in the exploration phase they were intentionally seeking focus points, and in formulation they were again trying to make predictions to predict outcomes. These actions are about trying to move the process forward; does it work if I do this, what happens if I were to try this? This is classic experimental thinking applied to an under-specified task.

ISP involves *iteration* and *approximation*. The movement from earlier general activities and understandings to later more precise and focused ones emphases iterative approaches. This is especially clear in the collection phase with its emphasis on defining, extending, and supporting the focus, that is, working from an existing point and gradually developing (shaping) it to a more desired form. There is also a sense in the formulation phase of an end-goal emerging gradually from these actions. The whole story of the ISP is general broad shaping gestures followed by precise actions with more control and predictability. Indeed Kuhlthau refers to it as a "*recursive, iterative process*" (Kuhlthau, 1993).

Finally, the ISP is *perceptual*. This is not a focus of the ISP but implicit in much of the model. When Kuhlthau uses the word perception she typically means the cognitive understanding and assessment of the task. However, one of the most interesting features of the ISP is that it maps what the students were physically doing alongside their cognition. Throughout the description of the ISP we see perceptual activities in which students use their visual abilities to create maps of where information is, how much there is, and make judgments based on perception.

Kuhlthau's ISP takes place within a social learning framework. It is specifically a learning process, but we see the social learning occur, particularly in the earliest phases, such as "*talking with others*," "*brainstorming*," "*consulting with informal mediators*," and "*relating prior experiences and learning*" which emphasizes that existing cultural solutions are a primary source to create new solutions.

5.2 | Vakkari and task-focused searching

In the early 2000s, Vakkari was interested in how relevance decisions and search behaviors changed over a longitudinal search process (Vakkari, 2000, 2001; Vakkari & Hakala, 2000). Like Kuhlthau, his investigation was based an educational task, creating a research proposal for a Master's thesis. A strong focus of this research was on the students' cognitive understandings of the domain and their mental models of the task as they were represented by the ways in which in the students searched for information at different phases of the task (Vakkari, 2000).

In these studies, we again see principles of shaping. The shaping processes of broad to specific are shown clearly in two ways. First, at the start students preferred more general information in the form of encyclopedia entries, overviews and reviews as these "*give them an overview of the topic and show possible frames and problem formulation*" (Vakkari & Hakala, 2000, p. 554). So here we see the broad initial shaping gestures described as key to shaping processes and that they are benefitting from socially constructed ways of providing information, the "*frames*." Toward the end of the task, they were primarily looking for specific information (Vakkari, 2001), that is looking for more precise information that fitted with smaller, more focused shaping gestures.

Second, the *way* that students searched also varied as they progressed through the task. At the start, students paid a lot of attention to assessing documents in a general way (Vakkari, 2000) while at the end they are more able to distinguish relevant and non-relevant documents (Vakkari, 2000). Initially queries were simple in terms of number of terms used and facets compared to later queries (Vakkari, 2000) which reflected "*growing mastery of terminology*" (p. 900) as they sought to use search operators to make queries more precise and more multifaceted (Vakkari, 2000). Broader terms were dropped as the search progressed in favor of more precise terms, synonyms, and related terms (Vakkari, 2001). They also used more search tactics as the task progressed, reflecting more sophisticated thinking about how to develop the search requests and more specific understandings of what information was required (Vakkari, 2000). Vakkari was also very eloquent in describing the iterative and successive ways that students used search operators which all suggest an experimental and approximation-based way of working with the search systems and databases to shape the information to the required form.

Therefore, we can see patterns that are consistent with shaping principles: broad gestures at the start to create a guide for later, more focused and specific interactions that have greater predictability and where the shaper can more clearly see the end result. As with the ISP the students are working to optimize the material they have, and are experimenting with the material to test the results of their actions on the task. Like the ISP there is a perceptual component in that the students see their actions, in terms of querying, in the form of differences in the retrieved data sets.

Other studies have also demonstrated similar findings: that earlier stages in task involve coarser orientation

actions followed by more task-specific ones (Tombros et al., 2005), that people often engage in superficial assessments of information to narrow searches to useful regions (Savolainen, 2017) before detailed investigations, that focusing of a task is often associated with greater precision in searching (Wang, 1997), and that searchers pattern-build when interacting with search results by using initial search results to create a scaffold to interpret later ones (Florance & Marchionini, 1995).

5.3 | Ruble and transitions

Shaping processes are not only observed in situations where there is an information artifact being created but also where the result is less tangible. Ruble, for example, proposed three stages of transitions with specific focus on identity development and information use (Ruble, 1994).

Phase 1, *Construction*, is proposed to occur once an individual enters a new psychological situation in which their old knowledge base and expectations may not apply, such as becoming pregnant for the first time. Knowledge is low and often superficial, information seeking is focused on defining basic procedures and features of the new situation, information assessment is based on topical relevance, is generic and without any specific purpose in mind.

Phase 2, *Consolidation*, is when sufficient knowledge has been acquired that the individual can start to apply the knowledge to themselves and their own situation, they can create focus points, draw inferences, their information seeking is more focused toward knowledge goals, their assessment is based on topical and situational factors and therefore the emotional impact of information is higher. At this stage, Ruble argues that schemas (models of solutions) are being developed that guide future information activities to gain information that is consistent with the schemas being developed.

Phase 3, *Integration*, relates to processes to define, maintain, and enlarge the conclusions and understandings created in the previous stages. Less information is accepted here, and that information is usually information that is highly personal. Information seeking tends to be more passive, as the solution has been developed, and information that is inconsistent with previously created understanding is being resisted.

The movement is therefore again general to specific, from general understandings of a situation toward specific understandings of an individual situation. Again, the situation is developing, and the process is iterative and approximate—moving from simply gaining background information to iteratively focusing the information, using it to create inferences about the information gained and its implications to their own situation and then to more information seeking. Although Ruble does not phrase it this way, the use of inferences (something to be tested) also suggests experimentation through information use. What is also clear is that once a solution has been determined in the consolidation phase, then the future information work is to develop and maintain this solution. As with shaping stone tools, the more we commit to an existing solution, the less likely we are to radically change it.

As with other models and theories of transitions, see for example the discussions in Ruthven (2022a, 2022b), there is an iterative process of understanding generally what a transition may involve before periods of more focused information work to shape a final solution. In many cases this involves experimentation to see the effect of information in action, feedback loops to direct future actions, and a movement from general possible outcomes to more specific, concrete ones. All of this takes place within social environments in which some solutions are socially favored, prepared for, discussed, and facilitated while others are deemed socially inappropriate and may be actively discouraged (Ruthven, 2022a). That is, social learning environments make some transitions easier and provide patterns and ways to learn about them, while others are hidden, and solutions have to be created without reference to existing ways of doing things and therefore involve more experimentation.

5.4 | Allard and Caidi and migration

Shaping processes can also be observed in situations where there are radical changes to one's live. For example, Allard and Caidi (2018) posited a five-step process of what they referred to as Translocal Meaning-Making, the process of making meaning out of the information that migrants encounter or are provided with as they move to another locale. They describe a process by which migrants first imagined a new life in another country by using available information, including others' narratives, then dissonance when they realized their gaps in knowledge, increasing sophistication as personal experiences lead to greater understanding of local practices and context, alongside an ongoing process of reflection on the original imagined life, followed by reimagining their new location and their migration experience.

In Allard and Caidi's account we again see how general moves to specific. In their description of migrants' increasing sophistication in their new environments, they note that "*participants' information practices move from general, unspecific … to explicit, independent, and considerably more sophisticated. Upon arrival, participants' information-seeking strategies were often quite*

general and included various forms of browsing." (p. 1198). Over time, their information practices become "*more diverse, varied, and sophisticated*" (p. 1198) and they become more able to navigate complex information environments.

We also see how social learning is important as migrants' learning in the early stages of migration was based on "*observation, conversation, and mimicry*" (p. 1197) especially of those closest to them. They have to make use of what is available to them and optimize opportunities to gain information, fitting with the principle of local optimization. Allard and Caidi also demonstrate the iterative, approximation-based nature of learning to exist within new physical spaces, "*migration-related information practices are iterative and move from imaginary to experiential and back again as migrants gain an understanding of their current information landscapes*" (p. 1198) and their accounts are very strong on the embodied and perceptual nature of migration.

6 | DISCUSSION

Evolution and culture interact in complex and often unpredictable ways. It just as simplistic to believe that all human behavior has evolutionary explanations as it is to believe that somehow humans have outgrown evolutionary factors, and we are only reliant on socio-cultural factors. The argument proposed here is that the primary way that humans have evolved to interact with the world is through a perceptual combination of hands and eyes. Our hands allow us to sense and shape the world around us, enacting cognition as the interplay between our brains, hands, eyes, and our material environment. For millions of years this is how humans have worked with the world. This has given us innate ways of thinking about interaction with the world that have become absorbed into ways of using information which have been overlaid by social and cultural traditions.

The perceptual and material aspects of information work are under-explored in our discussions of information activities with more emphasis on cognition, and more recently, emotion. However, the perceptual and material aspects constantly emerge in our language of information work with talk of cutting, pasting, sorting, arranging, organizing, weeding, and so forth and in how we interact with information, for example if we examine Bates' list of search tactics we find WEIGHT, SELECT, CUT, STRETCH, SCAFFOLD, CLEAVE, REDUCE, PINPOINT, REARRANGE (Bates, 1979), rich in physical connotations of interacting with material.

We have expanded our capabilities through tools that are created to solve problems that arise in our everyday environments. These tools are created through processes described as shaping processes which have distinct characteristics. These tools, and the processes used to create them, are part of a community's stock of knowledge and skills: they are used by individuals to develop new solutions and act as a cohesion device for the community. Some authors (e.g., Hutchence & Scott, 2021) have found ideas from Wenger's work on communities of practice useful here, especially the idea that "*through the production of a shared repertoire of actions and artefacts, members make material the abstract ideas related to their membership and identity*" (p. 681) while also showing that individual tool production can result in novelty due to the characteristics of the shaping processes: innovation generally occurs within existing frameworks for thinking about the world. This is especially the case where the processes being used rely on experimentation and iteration.

Arguably this has many connections to our information work in which existing norms, practices, organizational cultures, and standardized information forms encourage certain ways of doing things while not prescribing the result. The term papers investigated by Kuhlthau for example were created within environments in which these papers were a regular form, supported by information environments such as libraries, and people such as teachers who were experienced in the form. However, the students did not all create the same outcome: their own innovation and actions shaped different outcomes which were different but recognizable as the same type of solution. In Vakkari's studies we also see social practices arise in the form of the databases with which the students were interacting and social learning in how to use these tools to create their final artifact.

Shaping processes involve many information activities to create a final form. In Information Science, we rarely study long running tasks or information challenges that require *coordinated* responses using multiple information behaviors. Articles focused on tasks, such as Kuhlthau or Vakkari, or later works that consider task conceptually or empirically (e.g., Soufan et al., 2021), point to different activities happening at different points but usually at a high-level. Taking a shaping perspective, we can focus more on the use of information and how it contributes to a final form.

I am not proposing that all information use is the same or works on the same principles. Simple types of information use such as fact-checking will not require shaping processes; rather information shaping comes into play for certain types of information problem where information must be transformed to be of use. Here, the ways we do these transformations are gifted to us within social learning environments that emphasize imitation

(following existing patterns and processes) but also allow for innovation and individualization.

Shaping is not simply a case of one object being transformed into another but describes how available resources are assembled and brought into a solution for a current concern. Taking a shaping perspective on information use emphasizes how we work with information. In doing so, it foregrounds notions of making information and information solutions (Huvila, 2022), and activities such as crafting or bricolage (Lea French & Williamson, 2016) by which information solutions come into being. Shaping also emphasizes perception, enacted cognition, and the materiality of information use, aligning with new ideas on the sensuality of information work (Keilty & Leazer, 2018).

Shaping as an evolutionary process, and one heavily investigated in evolutionary studies and studies of cognition, also offer us new ideas for studying information use and how our information practices come into being and their links with our wider interactions with the world. It complements existing theories such as Information Foraging but with a distinctive focus on information use. The proposed value of Information Shaping is to better understand how we use information, place our uses of information within a social learning framework, and develop fruitful questions about information use.

7 | CONCLUSION

This article seeks to link the ways in which humans have evolved to interact with the world with how they interact with information. This provides a broad theoretical base for investigating our information behaviors and how we create information solutions by viewing them as extensions of how we create other types of solution. Ideas from evolutionary and social learning theory as to how we individually and collectively develop solutions can support new theorizing about the relationship between information work and other types of work and identify under-explored areas of Information Science study such as the perceptual and material aspects of information work.

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ENDNOTES

[1] Some of the ideas presented here were introduced in Ruthven (2022a). *Dealing with Change Through Information Sculpting*. Emerald. This paper presents significant new material and a much fuller account of the proposals made there.

[2] Similar arguments about cost–benefit motivations applied to information use were discussed earlier by Herbert Poole in Theories of the Middle Range, Ablex Publishing Corporation, 1985. I am grateful to the reviewer who pointed this out.

REFERENCES

Allard, D., & Caidi, N. (2018). Imagining Winnipeg: The translocal meaning making of Filipino migrants to Canada. *Journal of the Association for Information Science and Technology*, *69*(10), 1193–1204. https://doi.org/10.1002/asi.24038

Aydin, K., Ucar, A., Oguz, K. K., Okur, O. O., Agayev, A., Unal, Z., Yilmaz, S., & Ozturk, C. (2007). Increased gray matter density in the parietal cortex of mathematicians: A voxel-based morphometry study. *American Journal of Neuroradiology*, *28*(10), 1859–1864. https://doi.org/10.3174/ajnr.A0696

Bates, M. J. (1979). Information search tactics. *Journal of the American Society for Information Science*, *30*(4), 205–214. https://doi.org/10.1002/asi.4630300406

Bates, M. J. (1989). The design of browsing and berrypicking techniques for the online search interface. *Online Review*, *13*(5), 407–424. https://doi.org/10.1108/eb024320

Bates, M. J. (2005). Information and knowledge: An evolutionary framework for information science. *Information Research: An International Electronic Journal*, *10*(4), n4.

Bates, M. J. (2018). Concepts for the study of information embodiment. *Library Trends*, *66*(3), 239–266. https://doi.org/10.1353/lib.2018.0002

Bates, M. J. (2022). A proto-paradigm for information science research. *Information Research*, *27*(4). https://doi.org/10.47989/colis2201

Boaretto, E., Barkai, R., Gopher, A., Berna, F., Kubik, P. W., & Weiner, S. (2009). Specialized flint procurement strategies for hand axes, scrapers and blades in the late lower paleolithic: A 10Be study at Qesem cave, Israel. *Human Evolution*, *24*, 1–12.

Bruner, E., Spinapolice, E., Burke, A., & Overmann, K. A. (2018). Visuospatial integration: Paleoanthropological and archaeological perspectives. In L. D. di Paolo, F. di Vincenzo, & F. de Petrillo (Eds.), *Evolution of primate social cognition* (pp. 299–326). Springer. https://doi.org/10.1007/978-3-319-93776-2_19

Burton, G. J., Moffett, A., & Keverne, B. (2015). Human evolution: Brain, birthweight and the immune system. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *370*(1663), 20140061. https://doi.org/10.1098/rstb.2014.0061

Byström, K., & Järvelin, K. (1995). Task complexity affects information seeking and use. *Information Processing & Management*, *31*(2), 191–213. https://doi.org/10.1016/0306-4573(95)80035-R

Creanza, N., Kolodny, O., & Feldman, M. W. (2017). Cultural evolutionary theory: How culture evolves and why it matters. *Proceedings of the National Academy of Sciences*, *114*(30), 7782–7789.

De Petrillo, F., Di Vincenzo, F., & Di Paolo, L. D. (2018). An evolutionary perspective on primate social cognition. In L. D. di

Paolo, F. di Vincenzo, & F. de Petrillo (Eds.), *Evolution of primate social cognition* (pp. 1–10). Springer.

Florance, V., & Marchionini, G. (1995). *Information processing in the context of medical care*. Paper presented at the Proceedings of the 18th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval, Seattle, WA. https://doi.org/10.1145/215206.215353

Gaser, C., & Schlaug, G. (2003). Gray matter differences between musicians and nonmusicians. *Annals of the New York Academy of Sciences*, *999*(1), 514–517. https://doi.org/10.1196/annals.1284.062

Harmand, S., Lewis, J. E., Feibel, C. S., Lepre, C. J., Prat, S., Lenoble, A., Boës, X., Quinn, R. L., Brenet, M., Arroyo, A., Taylor, N., Clément, S., Daver, G., Brugal, J.-P., Leakey, L., Mortlock, R. A., Wright, J. D., Lokorodi, S., Kirwa, C., … Roche, H. (2015). 3.3-Million-year-old stone tools from Lomekwi 3, West Turkana, Kenya. *Nature*, *521*(7552), 310–315. https://doi.org/10.1038/nature14464

Haslam, M., Falótico, T., & Luncz, L. (2018). Recognizing culture in wild primate tool use. In *Evolution of primate social cognition* (pp. 199–209). Springer.

Hertzum, M. (2023). Information seeking by experimentation: Trying something out to discover what happens. *Journal of the Association for Information Science and Technology*, *74*(4), 383–387. https://doi.org/10.1002/asi.24740

Hutchence, L., & Scott, C. (2021). Is Acheulean Handaxe shape the result of imposed 'mental templates' or emergent in manufacture? Dissolving the dichotomy through exploring 'communities of practice' at Boxgrove, UK. *Cambridge Archaeological Journal*, *31*(4), 675–686. https://doi.org/10.1017/S0959774321000251

Huvila, I. (2022). Making and taking information. *Journal of the Association for Information Science and Technology*, *73*(4), 528–541. https://doi.org/10.1002/asi.24599

Keilty, P., & Leazer, G. (2018). Feeling documents: Toward a phenomenology of information seeking. *Journal of Documentation*, *74*(3), 462–489. https://doi.org/10.1108/JD-09-2016-0113

Kuhlthau, C. C. (1993). *Seeking meaning: A process approach to library and information services*. Ablex.

Lea French, R., & Williamson, K. (2016). The information practices of welfare workers: Conceptualising and modelling information bricolage. *Journal of Documentation*, *73*(4), 737–754. https://doi.org/10.1108/JDOC-08-2015-0100

Legare, C. H. (2017). Cumulative cultural learning: Development and diversity. *Proceedings of the National Academy of Sciences*, *114*(30), 7877–7883.

Lockman, J. (2005). Tool use from a perception–action perspective: Developmental and evolutionary considerations. In V. R. B. Bril (Ed.), *Stone knapping: The necessary conditions for a uniquely hominin behaviour* (pp. 319–330). McDonald Institute Monographs.

Madden, A. D. (2004). Evolution and information. *Journal of Documentation*, *60*(1), 9–23. https://doi.org/10.1108/00220410410516626

McKenzie, P. J. (2003). A model of information practices in accounts of everyday-life information seeking. *Journal of Documentation*, *59*(1), 19–40. https://doi.org/10.1108/00220410310457993

Muller, A., Shipton, C., & Clarkson, C. (2022). Stone toolmaking difficulty and the evolution of hominin technological skills. *Scientific Reports*, *12*(1), 5883. https://doi.org/10.1038/s41598-022-09914-2

Paolo, L. D. D., & Vincenzo, F. D. (2018). Emulation, (over)imitation and social creation of cultural information. In *Evolution of primate social cognition* (pp. 267–282). Springer.

Pargeter, J., Khreisheh, N., Shea, J. J., & Stout, D. (2020). Knowledge vs. know-how? Dissecting the foundations of stone knapping skill. *Journal of Human Evolution*, *145*, 102807. https://doi.org/10.1016/j.jhevol.2020.102807

Piltch-Loeb, R., Savoia, E., Goldberg, B., Hughes, B., Verhey, T., Kayyem, J., Miller-Idriss, C., & Testa, M. (2021). Examining the effect of information channel on COVID-19 vaccine acceptance. *PLoS One*, *16*(5), e0251095.

Pirolli, P., & Card, S. (1995). *Information foraging in information access environments*. Paper presented at the Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Denver, Colorado. https://doi.org/10.1145/223904.223911

Pirolli, P., & Card, S. (1999). Information foraging. *Psychological Review*, *106*(4), 643–675. https://doi.org/10.1037/0033-295X.106.4.643

Reindl, E., Bandini, E., & Tennie, C. (2018). The zone of latent solutions and its relation to the classics: Vygotsky and Köhler. In *Evolution of primate social cognition* (pp. 231–248). Springer.

Renner, E., & Zawidzki, T. (2018). Minimal cognitive preconditions on the ratchet. In L. D. di Paolo, F. di Vincenzo, & F. de Petrillo (Eds.), *Evolution of primate social cognition* (pp. 249–265). Springer.

Ruble, D. N. (1994). A phase model of transitions: Cognitive and motivational consequences. In M. P. Zanna (Ed.), *Advances in experimental social psychology* (Vol. 26, pp. 163–214). Academic Press. https://doi.org/10.1016/S0065-2601(08)60154-9

Ruthven, I. (2022a). *Dealing with change through information sculpting*. Emerald.

Ruthven, I. (2022b). An information behavior theory of transitions. *Journal of the Association for Information Science and Technology*, *73*(4), 579–593. https://doi.org/10.1002/asi.24588

Savolainen, R. (1995). Everyday life information-seeking—Approaching information-seeking in the context of way of life. *Library & Information Science Research*, *17*(3), 259–294. https://doi.org/10.1016/0740-8188(95)90048-9

Savolainen, R. (2007). Information behavior and information practice: Reviewing the "umbrella concepts" of information-seeking studies. *The Library Quarterly: Information, Community, Policy*, *77*(2), 109–132. https://doi.org/10.1086/517840

Savolainen, R. (2017). Heuristics elements of information-seeking strategies and tactics: A conceptual analysis. *Journal of Documentation*, *73*(6), 1322–1342. https://doi.org/10.1108/JD-11-2016-0144

Savolainen, R. (2018). Berrypicking and information foraging: Comparison of two theoretical frameworks for studying exploratory search. *Journal of Information Science*, *44*(5), 580–593. https://doi.org/10.1177/0165551517713168

Shipton, C., & Clarkson, C. (2015). Handaxe reduction and its influence on shape: An experimental test and archaeological case study. *Journal of Archaeological Science: Reports*, *3*, 408–419. https://doi.org/10.1016/j.jasrep.2015.06.029

Soufan, A., Ruthven, I., & Azzopardi, L. (2021). *Untangling the concept of task in information seeking and retrieval*. Paper presented at the Proceedings of the 2021 ACM SIGIR International

Conference on Theory of Information Retrieval, Virtual Event, Canada. https://doi.org/10.1145/3471158.3472259

Spink, A. (2010). *Information behavior: An evolutionary instinct*. Springer-Verlag. https://doi.org/10.1007/978-3-642-11497-7

Tennie, C., Bandini, E., van Schaik, C. P., & Hopper, L. M. (2020). The zone of latent solutions and its relevance to understanding ape cultures. *Biology and Philosophy*, *35*(5), 55. https://doi.org/10.1007/s10539-020-09769-9

Tombros, A., Ruthven, I., & Jose, J. M. (2005). How users assess web pages for information seeking. *Journal of the American Society for Information Science and Technology*, *56*(4), 327–344. https://doi.org/10.1002/asi.20106

Vakkari, P. (2000). Cognition and changes of search terms and tactics during task performance: A longitudinal case study. In *Content-based multimedia information access* (Vol. 1). LE CENTRE DE HAUTES ETUDES INTERNATIONALES D'INFORMATIQUE DOCUMENTAIRE.

Vakkari, P. (2001). A theory of the task-based information retrieval process: A summary and generalisation of a longitudinal study. *Journal of Documentation*, *57*(1), 44–60. https://doi.org/10.1108/EUM0000000007075

Vakkari, P., & Hakala, N. (2000). Changes in relevance criteria and problem stages in task performance. *Journal of Documentation*, *56*(5), 540–562. https://doi.org/10.1108/EUM0000000007127

Wang, P. (1997). User's information needs at different stages of a research project: A cognitive view. In P. Vakkari, R. Savolainen, & B. Dervin (Eds.), *Information seeking in context* (pp. 307–318). Graham Taylor.

Watson, S. K., Botting, J., Whiten, A., & van de Waal, E. (2018). Culture and selective social learning in wild and captive primates. In L. D. di Paolo, F. di Vincenzo, & F. de Petrillo (Eds.), *Evolution of primate social cognition* (pp. 211–230). Springer Verlag.

Weedman, K. J. (2006). An ethnoarchaeological study of hafting and stone tool diversity among the Gamo of Ethiopia. *Journal of Archaeological Method and Theory*, *13*(3), 189–238. https://doi.org/10.1007/s10816-006-9010-4

Woollett, K., & Maguire, E. A. (2009). Navigational expertise may compromise anterograde associative memory. *Neuropsychologia*, *47*(4), 1088–1095. https://doi.org/10.1016/j.neuropsychologia.2008.12.036

Yates, J. A., & Orlikowski, W. J. (1992). Genres of organizational communication: A structurational approach to studying communication and media. *Academy of Management Review*, *17*(2), 299–326. https://doi.org/10.2307/258774

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