Reconsidering healthcare evidence as dynamic and distributed: the role of information and cognition

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ABSTRACT

Aim The basic thrust of evidence-based healthcare is that current best evidence should be used explicitly and judiciously for diagnosis, management, and other activities in healthcare settings. For this to be possible, researchers, practitioners, and other stakeholders must have a clear and accurate conceptualization of what constitutes 'evidence' in healthcare environments, and the manner in which it is used in decision-making and other activities. Currently, the dominant conceptualization of evidence is that of a body of information that can be retrieved by stakeholders for use in healthcare practice. The aim of this article is to critically examine the concept of evidence, particularly in light of recent models of human cognition and information use in decision-making and other cognitive activities.

Methods In this theoretical article, we employ both analytical and synthetic methods to critically examine the concepts under investigation. Key concepts, such as evidence and information, and the essential relationships between them are analyzed from the vantage point of cognitive science, information science, and other relevant disciplines to explicate a conceptualization of evidence that moves past static and objectivist accounts.

Results We demonstrate that evidence is fundamentally information that takes various forms—i.e., artifacts, mental structures, or communication processes. Specific forms and manifestations of evidence can thus be described in the context of information use in dynamic information environments. Furthermore, evidence-based healthcare activities are shown to be fundamentally cognitive in nature. For any given evidence-based healthcare activity, its quality and outcome can be understood in the context of how different sources of evidence are coordinated within a distributed cognitive system. In this sense, evidence based health care activity becomes more a matter of understanding the movement of information and knowledge within a distributed and dynamic cognitive system than mere access to or translation of a ready-at-hand resource.

Conclusions The conceptualization of evidence presented in this article has a number of implications for evidence-based healthcare—in terms of where attention is focused, the direction of future research efforts, how evidence generation, use, and practice are conceptualized and discussed, and how healthcare technologies are designed and evaluated. Furthermore, the conceptualization presented in this article has implications for the manner in which evidence 'hierarchies' are developed. Such hierarchies do not provide a complete picture of evidence and the way it is used in healthcare activities. Understanding the dynamic nature of evidence and its role in distributed cognitive activities may lead to more robust and multi-faceted taxonomies, frameworks, and hierarchies related to evidence-based healthcare.

Key words: cognitive activities, conceptualization of evidence, distributed cognition, distributed cognitive systems, information, information environment, knowledge

Introduction

A general tenet of modern healthcare is that the best and most current available evidence should be used to inform healthcare decision-making and practice.[1] Such is the basic thrust of evidence-based healthcare (EBHC). Despite a number of successes in EBHC research, some lingering difficulties exist, particularly in

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conceptualizing the nature of evidence and the meaning of evidence use. Researchers in the EBHC domain have tended to define the quality and utility of evidence in objective and impersonal terms – for example, as an outcome of the methodological rigor with which a body of information or knowledge is produced.[2] This conceptualization of evidence, however, has tended to divert focus from understanding the factors that are relevant to evidence use, and the relationships between and among these factors in context.[3–5]

One source of difficulty in this regard is a lack of necessary attention paid to the role of cognitive tasks and activities (e.g. interpretation, analysis, decision-making) in which EBHC stakeholders (e.g. physicians, nurses, pharmacists, epidemiologists) engage when performing evidence-based activities. Adding to this issue is an underemphasis on the role that representational media – the artifacts, stakeholders, and systems that carry, transform, or display task-relevant information within the information environment (e.g. healthcare setting) – have in influencing the manner in which evidence is accessed and used in stakeholder activities. Currently, the dominant conceptualization of evidence is that of a body of information or knowledge (e.g. systematic reviews and results from randomized control trials) that can be accessed by stakeholders for use in healthcare practice.[6–10] In this article, we argue that this dominant conceptualization addresses only one aspect of what constitutes the full scope of evidence that is used in healthcare activities. More specifically, we argue that evidence is a dynamic phenomenon that is distributed across representational media, and emerges from the processing and propagation of 'representational states of information' within healthcare environments. Furthermore, we posit that a successful EBHC activity requires the 'effective coordination' of representational media within healthcare environments, such that the various media can work together harmoniously to accomplish desired goals and tasks.

This article is organized as follows: we present the current, common conceptualization of evidence in the EBHC discourse; we discuss the role of information and information environments in conceptualizing evidence and EBHC activities; we identify and describe the inadequate models of cognition that have been assumed into EBHC discourse, and describe more recent models of cognition and how they are related to EBHC; we bring the previously described ideas together to re-examine the concept of evidence; and we discuss the main contentions of the article and some implications for EBHC, and make some suggestions for future work that can build on and benefit from the conceptualization put forward in this article.

Common conceptualization of evidence

Perhaps the most common conceptualization of evidence is that of a body of information or knowledge that can be accessed and used to support systematic, principled decision-making. Examples of such 'evidence' are results from randomized trials, systematic reviews, and observational studies. This conceptualization is best expressed in the so-called hierarchies of evidence.[11–14] Such hierarchies tend to rank the value of different forms of evidence, typically placing systematic reviews and randomized control trials at the top; observational studies, surveys, and case reports in the middle; and expert clinical judgment at the bottom. From this perspective, it appears that the methodological features of the evidence base, such as the study design,[15] validity,[16] reliability, and type of evidence,[10,17] receive the most attention in determining the 'quality' of evidence. From this it follows that a central task of EBHC is conducting research to produce 'evidence', which can then be used to find and implement the 'best practices' in key areas of clinical and public health decision-making. To this end, evidence hierarchies and grading systems are employed to encourage the use of methodologies that produce evidence embodying the highest degree of internal validity. This has led to the internal validity of evidence being consistently overemphasized, whereas the development of a rich understanding of other aspects related to the goals of a healthcare intervention, or the context of its implementation, has been comparatively underemphasized or de-emphasized.[18,19] Concomitantly, the purpose of EBHC as a whole has, at times, been reduced to 'gap filling' in the evidence base – effectively positioning the evidence base as the primary area of focus and the primary determinant of the quality of outcome.[20] As a consequence of this attitude and approach, the evidence base is often viewed as the panacea to all the problems in healthcare, with little consideration as to when, how, or by whom such evidence should be used.[21,22] Thus 'evidence', when viewed from this perspective, is typically considered to be synonymous with 'evidence base'; in other words, evidence is conceived of as an objective, codified body of information or knowledge.[23]

Although this conceptualization of evidence seems to have received the most attention and support, it has not escaped the criticism of a number of researchers. For instance, in his book on the philosophy of evidence-based medicine, Howick[14] identifies a number of

paradoxes that arise as a result of the typical evidence hierarchy. One such paradox lies in the fact that many of our most trusted treatments, such as external defibrillators, the Heimlich maneuver, tracheostomies, and penicillin, have never been supported by randomized control trials, and although they are widely regarded to not require such validation, the evidence hierarchy categorically rejects them from its pinnacle. Shedding further doubt on the completeness of the evidence hierarchy is the fact that some treatments that have support from randomized control trials have highly undesirable side effects and are hotly disputed.[24,25] A number of other researchers have attempted to address the shortcomings of this aforementioned dominant conceptualization, seemingly in one of the two ways: by attempting to situate evidence within considerations of 'context', and by expanding the scope of what can be constituted as evidence. In the first strategy for addressing existing shortcomings, decisions made on the basis of evidence need to be balanced and weighed next to other extra-evidentiary considerations. For example, EBHC stakeholders must take into account organizational or local culture, patient preferences, or tacit/practice-based knowledge.[6,26–30] Others have pointed out that some types of evidence are inherently subjective and defy codification and quantification,[31–33] whereas some have even suggested that objective and subjective information are mutually constitutive and can never be dissociated in real life.[34,35] In the second strategy for addressing existing shortcomings, certain types of 'knowledge' in themselves are included within the scope of the concept of evidence. For example, clinician experience, patient experiences, local circumstances, and culture can be considered as forms of 'evidence'.[36–38] Apart from this, the social sciences have increasingly been brought to bear on the conceptualization of evidence. Their methodologies tend to capture the subjective, narrative, 'meaningful', and experiential aspects of knowledge,[7,20,31,34,38–40] and are often aimed at supplementing the quantitative, general, and 'rationalistic' conceptions of evidence with those that are qualitative, personal, and particular.

Currently, many researchers do suggest that a combination of qualitative and quantitative information, encompassing scientific studies, systematic reviews, patient values, and other contextual factors, should enter into EBHC decision-making.[10,18,41] The question still remains, however, as to how different types of information and knowledge are integrated, combined, structured, and organized to support their optimal use in EBHC activities. Although a number of researchers have recognized and attempted to address such aforementioned shortcomings, and have offered critiques and alternative conceptualizations of evidence, none have explicitly informed the conceptualization with recent models of cognition and information use in cognitive activities – issues which we argue are of fundamental importance in the EBHC discourse. Thus, our main intention here is not simply to point out shortcomings in previous conceptualizations of evidence – whether with respect to the evidence base, evidence hierarchies, or otherwise – rather, our intention is to make a contribution to the discourse on evidence by incorporating recent research on the performance of information-based (e.g. evidence-based) cognitive activities that take place in dynamic information environments (e.g. healthcare environments). We contend that an accurate understanding of the role of cognition – particularly with respect to the propagation of representational states in distributed cognitive systems – and of the fundamental nature of information and its use in cognitive activities is essential for an informed conceptualization of evidence in EBHC.

Information and information environments

The most basic definition of information is 'ordered matter and energy'.[42,43] While this definition is accurate and useful in a general sense, three specific types of information that build on this basic definition are useful in the context of EBHC: information as internal, mental states, and structures; information as a message, signal, or communication process; and information as a matter that has been shaped by people or computational agents for subsequent use – in other words, information as an artifact (see Marchionini[43] for an elaboration on these basic types of information). From this conceptual standpoint, it should easily become clear how many of the concerns of EBHC activity can be characterized in light of these three types of information. For instance:

(1) Information as internal, mental states, and structures: this type of information is concerned with the knowledge, expertise, and 'expert opinion' that individual stakeholders have, based on education, training, and clinical experience.
(2) Information as communication: this type of information is concerned with communication among stakeholders, between nurses and patients, and any other message or signal that is conveyed between entities or agents within a healthcare environment.
(3) Information as an artifact: this type of information is concerned with books, papers, reports, and other

documents; equipment and tools; computers, mobile devices, and other computational media.

The performance of evidence-based activities in healthcare contexts is deeply intertwined with the environments in which stakeholders are situated. On the basis of the definition of information above, healthcare environments can be accurately characterized as 'information environments'. Whether in the context of a physician and a patient in a clinical setting, an epidemiologist and a group of policymakers in a public health setting, or in any other healthcare setting in which 'evidence' is a concern, the three types of information are present and strongly influence the outcome of any activity that takes place. In other words, in EBHC settings, in general, there are stakeholders, artifacts, and communication signals and messages between those stakeholders and/or artifacts. In any specific setting, the information environment includes the space and elements that contribute to the generation, storage, manipulation, situation, contextualization, flow, and/or transfer of information – including, but not limited to, stakeholders, computational technologies, and other artifacts, and the physical, mental, and social space.

The activities of healthcare stakeholders take place within diverse information environments. These environments can be described as ranging from the so-called 'sharp end', which includes those characterized by fast-paced and highly dynamic team work, such as in hospital and clinical settings, to the 'blunt end', which includes those that are often slower, more complex, and encompass broader spatiotemporal problems, such as public health and health management.[6,21,44]

Cognition

Evidence-based stakeholder activities (e.g. diagnosis, prescription, policy formation, primary intervention) are fundamentally cognitive in nature. Policy formation, for example, relies on judgment, interpretation, apprehension, inference, mental comparison, and so on, all of which are basic cognitive processes. In other words, evidence-based activities in healthcare environments are inescapably cognitive in their very essence. As a result, it is critically important for researchers and practitioners to have an accurate understanding of the role of cognition in such activities. In reality, however, much of the EBHC literature has assumed so-called 'classical' (i.e. outdated and inaccurate) models of cognition into its discourse. In this section, we will describe the classical view of cognition; identify and briefly critique the commonly held view of cognition that is present in the EBHC literature; and examine the more recent 'distributed' view of cognition.

Classical view of cognition

In the past, cognition was viewed as a set of processes that took place primarily inside the head of an individual. From this perspective, human cognition is conceptually similar to the workings of an electronic computer – that is, some sort of logical, computational engine that receives information inputs, processes them in some manner, and produces behavioral outputs. From this perspective, the unit of analysis for studying human cognition is logically confined to the individual, and the external environment is considered to be of little or secondary consequence. The cognition of a doctor, for example, would be viewed as follows:

(1) A doctor receives some informational input to her cognitive system (e.g. patient symptoms seen by the doctor; patient history read by the doctor; patient's own description that is heard by the doctor; and so on).
(2) The information is processed – in the form of reasoning, judging, problem-solving, decision-making, and other internal processing – in the doctor's head along with her existing mental models and schemas.
(3) As a result of the processing, there are outputs in the form of behaviors (e.g. the doctor describes her diagnosis to the patient; the doctor prescribes a medication).

This view of cognition is often described in the cognitive science literature as the 'classical' view of cognition.[45,46] Although this view was useful and led to good research findings in certain contexts, it was not able to account for much of human cognitive ability and performance in a broader fashion.[46] As the shortcomings of this view became more evident, cognitive scientists began to develop a more holistic view of cognition that included the external environment in cognitive processing and activities. While this view has taken on a number of related labels, the most pertinent one for the purposes here is the 'distributed' view of cognition. We will describe this view after briefly examining the predominant view of cognition in the EBHC literature.

Predominant view of cognition in evidence-based healthcare literature

Activities that take place in healthcare environments are complex, dynamic, multilevel, and multifaceted.[47] In

the EBHC literature, however, the complex, emergent nature of cognitive activities that take place in healthcare environments is typically not part of the discourse. Owing to the complexity of such relationships, much of the research has taken a reductionist approach in an attempt to analyze the cognitive systems into component parts and study them in isolation. Such an approach is commonly seen in domains in which humans interact with information in complex ways.[41] This approach breeds a style of thinking that is, at least in part, responsible for the linearity and rigidity that characterize predominant approaches in EBHC.[47–49] In addition, the activity of decision-making is often conflated with the phenomenon of cognition in general. Indeed, research on decision-making is becoming increasingly important as a way to model evidence-based reasoning,[50,51] with some researchers going so far as to assert that the fundamental concern of EBHC is decision-making.[18,52] Furthermore, although valid research on decision-making is used extensively in medicine and healthcare, decision-making is often viewed through the lens of classical models of cognition as described previously – that is, cognition is assumed to function in an individualistic, stepwise, objective, and logical manner, where inputs are fed into the decision system and processed in consistent ways.[2] Some researchers have recognized this as a problem, and have made strides to rectify it. For example, Patel *et al.*[53,54] have attempted to broaden the basis of medical decision-making through naturalistic decision-making (NDM), which attempts to understand decision-making in real life, dynamic, ambiguous, and constrained environments. Although NDM is a step in the right direction, Hazlehurst *et al.*[55] have pointed out that emphasis on decision-making, in itself, imports classical assumptions about cognitive processes, placing primacy emphasis on the choices of individuals, whereas the larger information environment is recognized only peripherally. However, even without regard for the shortcomings mentioned by Hazlehurst *et al.*,[55] isolated advances in the medical decision-making literature, such as those made by Patel *et al.*,[53,54] have not yet found their way into the general discourse of EBHC. Despite the avowed importance of evidence-based decision-making, decision frameworks in EBHC are still predominantly linear and deterministic – in other words, they are based on inadequate models of human cognition. Whereas these extant decision-making frameworks certainly have some analytical value, they can also downplay and obscure the fundamental importance of the information environment in decision-making and other cognitive activities. Furthermore, although the distributed view of cognition has been used in some healthcare domains as a framework to understand and design medical devices and technology,[56–58] individual and team workflow,[59–63] medical education,[64] and decision-making,[53] it has not yet been explicitly incorporated into the EBHC discourse.

Distributed view of cognition

Rather than viewing cognition as a set of internal processes that receive input and produce output, the more recent, 'distributed' view conceptualizes cognition as a phenomenon that emerges from interactions among the brain, body, and external environment. From this perspective, cognition is considered to be situated and embedded in culture and activity; it is also spatially, socially, and temporally distributed. Consequently, the unit of analysis for cognition and cognitive activities is not confined to the individual; rather, it is the individual and the people, artifacts, and other objects in his or her external environment.[45,55] In other words, cognitive activities can be best understood as processes that 'emerge from relationships within a distributed cognitive system'. The important components in a distributed cognitive system are the information-bearing structures within that are relevant to and contribute to the performance of a cognitive activity.[65,66] These information-bearing structures are more specifically referred to as 'representational media' since they store, process, and propagate representations of information. At any point within a distributed cognitive activity, representational media manifest a particular configuration of information – 'a representational state' – within the system. Representational states are propagated within a distributed cognitive system across information channels via 'interpretive processes', which systematically convert the content (i.e. information) of one medium onto another. This process of 'propagation of representational states accounts for the cognitive performance of the distributed system as a whole', and thus serves as an organizing principle for the analysis and design of the system.[55,65] For instance, given a patient in a medical facility, information about a patient's status takes on different representational forms in the various media within the environment (e.g. a cardiac monitor, a nurse's notepad, a stethoscope). At any given instant, the relevant media have a representational state. Furthermore, the performance of any activity, such as diagnosis or prescription, depends on the propagation of these representational states throughout the various media within the environment – from the cardiac monitor, to the nurse's mental representations, to the notepad, and so on. In this case, the nurse serves as the primary interpretive agent

who integrates the various representations of information to decide on a final outcome (e.g. a diagnostic decision); however, the final outcome emerges from the processing and propagation of representational states throughout the system, and the various representational media all have an essential causal role in the outcome.

For a number of years now, cognitive scientists have held this view of cognition, and have found it useful and necessary for the description of dynamic, complex activities such as the one described above. For instance, this view is widely accepted to provide the most accurate description and explanation of cognitive processing that is distributed across representational media within sociotechnical systems, such as the bridge of a ship[65] or an airline cockpit.[67] In such cases, the system as a whole (e.g. cockpit, pilots, and technologies) is clearly the unit responsible for the outcome of an activity through distributed processing, storage, and propagation of information as representational states throughout the various media within the environment. Hutchins[65,68] has given very detailed descriptions of the workings of these distributed cognitive systems according to the view discussed above, and we will not repeat them here. These and other studies have clearly pointed to the inadequacy of viewing the individual as the sole or even primary determinant of outcomes of cognitive activities. It is worth noting that the distributed view of cognition is not simply a change in terminology; rather, it effects changes in the methodology of cognitive science research and in the explanatory methods of cognition itself.[46] As a result, there are a number of implications for how we understand the performance of cognitive activities in healthcare settings. Some of these will be discussed in the following section.

One of the key concerns in distributed cognitive environments is in understanding what influences the quality of distributed cognitive activities. Although particular environments have their own concerns, the main general concern of all distributed cognitive systems is that of 'coordination'. In other words, the key concern is how the representational states can be properly coordinated, through time and space, such that the whole system performs its activities effectively and optimally.[41,65,66] For example, in the previous example, the quality of the overall activity depends on the effective coordination of the nurse's mental representations, representational states of the various medical devices and other artifacts, as well as those of other people within the environment. Although a detailed discussion of the factors that contribute to the quality of coordination is outside the scope of this article, we will identify some of them in the section below.

Putting it together: re-examining the concept of 'evidence'

The fact that the 'evidence' that is used in decision-making and other EBHC activities is not simply a body of information should at this point be apparent. Furthermore, simply including contextual factors in the discussion of evidence use does not result in a coherent conceptualization of evidence that accounts for all the involved factors and components. If by 'evidence' we mean the things that we use to support and inform the most accurate and appropriate diagnosis, management, and other healthcare activities, we need to have a more robust view of the nature of evidence. Consider the performance of a complex medical activity such as the one mentioned in the previous sections. After the activity is performed, what should be considered as the 'evidence' that led to the outcome? What if the nurse had to consult with specialist, the patient, and the patient's family, and had to review patient records and a number of systematic reviews? Furthermore, what if the nurse rejected the treatment that was most strongly suggested by the systematic reviews due to some contextual factors (e.g. readings from a medical device)? For it to be considered as an evidence-based decision, it must have been based on evidence that was dynamic, not existing entirely in the original evidence base, and distributed throughout the healthcare environment in various representational media. Assuming a beneficial decision could be made, it would only be through the effective coordination of the representational media within the healthcare environment.

Perhaps some of the difficulty in conceptualizing evidence arises from the longstanding history of the term. If we view evidence as fundamentally information, however, we can avoid preconceived notions and can easily situate the concept within accurate models of distributed cognitive activities. In doing so, we can reach a level of descriptive and explanatory power for how 'evidence' informs and is used in real-world healthcare activities in a comprehensive, coherent manner. For example, evidence can be characterized according to the three types of information described previously: first, and probably most commonly, evidence is an artifact, that is, it is created by humans and/or other artifacts (e.g. computers) and is intended for subsequent use. For instance, a body of information (i.e. evidence) is accrued through randomized control trials and systematic reviews, and is integrated into an existing 'evidence base'. Second, evidence is stored and processed in internal mental states and structures; it is stored as knowledge in the head of a nurse, for example. This is the information (evidence) that comprises 'expert

opinion' that is used in clinical judgment. While some researchers refer to this as evidence and some do not,[6] it is, no doubt, a part of the interpretation process that contributes to evidence-based activities and their outcomes in healthcare settings. In fact, many clinicians assert that such information is an indispensible component of evidence-based activities.[9] Third, evidence is a message or communication process. Not only is current best evidence stored in and processed by artifacts, it is intentionally communicated to others, for example, through design of information systems, or the creation of systematic reviews, databases, and guidelines. If evidence is fundamentally information, we can describe its specific forms and manifestations in the context of information use in dynamic information environments. In doing so, we see that the 'evidence base' is just one aspect of the overall 'evidence' that is used in an activity. Furthermore, from this conceptual standpoint, we can identify the various representational media and their states at different points in the activity, and can describe the emergence of the outcome of the activity in the context of the propagation of these states within a distributed cognitive system. In doing so, it is possible to describe the whole activity with a high level of precision and rigor.

Implications and future work

The conceptualization of evidence presented in this article has a number of implications for EBHC. First, the roles and effects of the representational media within the information environment should be given more attention. It is not enough to give attention only to the evidence base, or even to consider contextual issues such as patient preferences. Future work in this regard could involve developing taxonomies or frameworks that explicate some of the general categories and features of representational media in healthcare environments. In addition, it is well known in the cognitive and perceptual sciences that different representational forms of information have significantly different effects on decision-making and other activities, even when the underlying information stays the same. This has implications for the design and evaluation of representations of evidence in different media. Future work could study and try to explicate the effects of different representational forms on the quality of evidence-based activities. A great deal of research is being done at the intersection of visual representation design and human cognition that could shed some light on this issue. Another important implication is that EBHC researchers should be concerned with understanding what leads to the effective coordination of representational states within a distributed cognitive system. In fact, this concern should be at the core of the whole discourse on evidence. One potential avenue of future work is in applying research from studies on interactive cognition to the issue of coordination in EBHC. For example, research has shown that the interactive opportunities that are afforded by an environment have a significant influence on the overall performance of an activity, and can promote, constrain, amplify, and shape different forms, styles, and strategies of thinking and reasoning.[69–71] This is especially true of interactive technologies that allow a rich discourse with information.[72,73] Further research in this area could spur the development of computational tools and other artifacts that are consciously designed from a perspective that incorporates the dynamic, distributed nature of evidence and of EBHC activities. Finally, the conceptualization presented in this article has implications for the manner in which evidence 'hierarchies' are developed. Although such hierarchies are perfectly accurate from a narrow perspective, they do not provide a complete picture of evidence and the way it is used in healthcare activities. In addition to an awareness of the paradoxes and problems mentioned previously, understanding the dynamic nature of evidence and its role in distributed cognitive activities may lead to more robust and multifaceted hierarchies of evidence. Perhaps this article will serve to stimulate research along some of the aforementioned avenues, and will contribute to the ongoing discourse on the nature and conceptualization of evidence on EBHC.

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