Clarifying Assumptions to Enhance Our Understanding and Assessment of Clinical Reasoning

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Abstract

Deciding on a diagnosis and treatment is essential to the practice of medicine. Developing competence in these clinical reasoning processes, commonly referred to as diagnostic and therapeutic reasoning, respectively, is required for physician success. Clinical reasoning has been a topic of research for several decades, and much has been learned. However, there still exists no clear consensus regarding what clinical reasoning entails, let alone how it might best be taught, how it should be assessed, and the research and practice implications therein.

In this article, the authors first discuss two contrasting epistemological views of clinical reasoning and related conceptual frameworks. They then outline four different theoretical frameworks held by medical educators that the authors believe guide educators' views on the topic, knowingly or not. Within each theoretical framework, the authors begin with a definition of clinical reasoning (from that viewpoint) and then discuss learning, assessment, and research implications. The authors believe these epistemologies and four theoretical frameworks also apply to other concepts (or "competencies") in medical education.

The authors also maintain that clinical reasoning encompasses the mental processes and behaviors that are shared (or evolve) between the patient, physician, and the environment (i.e., practice setting). Clinical reasoning thus incorporates components of all three factors (patient, physician, environment). The authors conclude by outlining practical implications and potential future areas for research.

Deciding on a diagnosis and instituting a treatment strategy are foundational to the practice of medicine. There is no question that developing competence in these processes, which are referred to loosely as "clinical reasoning," is essential for physician success. Clinical reasoning has been a topic of research for several decades and much has been learned, to include insights into how physicians generate and test hypotheses through hypothetical-deductive reasoning[1]; case specificity, which has been subsequently renamed "context-specificity" to account for the unique nature of the situation or encounter beyond the facts in the diagnosis portrayed[2–4]; dual process theory, which pertains to analytic and nonanalytic reasoning (or pattern recognition),[5] including its use in novices[6]; and script theory.[7,8]

Notwithstanding the many publications on clinical reasoning, there still exists no clear consensus regarding what clinical reasoning entails, let alone how it might best be taught and assessed, as well as the research and practice implications therein.[9] Because clinical reasoning lies at the core of what a physician does,[10] we believe this lack of consensus in the aforementioned domains could have a negative impact on the development of our learners and, ultimately, the care of their patients, because consensus in these domains is important to frame needed investigations and practices.

There are several definitions of *clinical reasoning*, and most do not converge to any great degree.[9] Some of the definitional confusion surrounding the term is likely due to the different epistemological and theoretical frameworks that medical educators use when discussing the topic. In this article, we begin by describing two contrasting epistemological views of clinical reasoning and related conceptual frameworks. We then outline four different theoretical frameworks held by medical educators that we believe guide their views of the topic, knowingly or not. Within each theoretical framework, we begin with a definition of clinical reasoning (from that viewpoint), and we discuss learning, assessment, and research implications. We end by outlining practical implications and potential future directions. We believe that discussing these frameworks (and their underlying assumptions) could help advance our understanding and assessment of clinical reasoning.

At the outset, we should note that we also believe that these two epistemological views and four theoretical frameworks and views apply to more than just clinical reasoning. As such, the issues discussed in this article could also apply to other medical education topics such as professionalism or clinical competence. However, in this article, we will use clinical reasoning as our primary example. Ultimately, we hope this article will help medical educators move the teaching and assessment of clinical reasoning from a largely "black

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box" topic to one where research can make important advances. We believe that making such advances constitutes a societal obligation in that helping our learners develop and improve clinical reasoning should eventually translate into improved care for our patients.

Epistemology

Epistemology involves the study of the nature, scope, construction, and limitations of a person's (or a group's) knowledge. It aims to answer questions such as, What is knowledge? How is it acquired? How do we know what we know? Research to date has found that clinical reasoning expertise combines both knowledge and experience, and, as such, we believe that understanding clinical reasoning's epistemology is *central* to understanding clinical reasoning.

From the standpoint of clinical reasoning, we often discuss two main epistemological perspectives: objectivist and constructivist. From the objectivist (or logical/positivist) perspective, for whichever domain is being considered (in this case, clinical reasoning), there is one truth that is revealed or can be discovered.[11] Thus, from this viewpoint, teaching can be thought of as the process of conveying this one truth, and learning can be thought of as the process of acquiring knowledge so that one can discover this one truth. Experience is seen as less important (because there is one truth to be discovered), and, as such, lectures, whereby experts convey their ideas on the truth, are seen as a pervading instructional method and an effective means of learning.

From the constructivist viewpoint, "knowledge is a compilation of human-made constructions"[12]—"not the neutral discovery of an objective truth."[13] From this perspective, teaching emphasizes providing learners with representative experiences. This is done so that, from a learning perspective, one can *construct* meaning. From this epistemological viewpoint, merely providing learners with static facts is insufficient for learning. Providing experiences whereby learners can construct meaning is key. The constructivist viewpoint has led, in part, to the emergence of problem-based and case-based learning; in these approaches, the teacher becomes a facilitator of learning as opposed to a lecturer or conveyor of facts. Stated another way, the teacher acts as "a guide on the side" as opposed to "a sage on the stage."

These two different epistemological perspectives—objectivist and constructivist—have relevance to clinical reasoning. The question becomes, is clinical reasoning a construct with one truth, or is it a construct that varies on the basis of the specifics of the situation and, notably, on the basis of the person doing the "constructing"? In other words, is clinical reasoning a trait or a state (varies with the situation), or a combination of the two? This is a central question to approaching the learning and assessment of clinical reasoning. Indeed, the perspective one takes leads to important assumptions and implications for the learning and assessment of clinical reasoning. The epistemological viewpoint taken will drive how one sees "signal," or true, variance and how one sees "noise," or error, variance in clinical reasoning.

Constructivism views knowledge as accruing between individuals by means of social interactions and social negotiation. Each individual's construction of this idiosyncratic relationship would be different—It is not the construction of one "truth." An example that illuminates this epistemological distinction that influences learning and assessment is student motivation. Many people think of motivation as a trait (either you have it or you don't), but others think of it as a state (you have it in certain circumstances, and/or the idea of motivation is constructed differently by different individuals—i.e., there is no one truth). A medical metaphor could be blood glucose measurement. If blood glucose measurement is a "trait," then one would expect the same findings with each value taken. If blood glucose is a state, then one would expect variability in measurements.

These two viewpoints would have different notions of error variance, or noise. For example, variation in student motivation would be seen as the expected "signal" from the "state" perspective, and as noise, or error, from the "trait" perspective. In other words, one's epistemological perspective drives how one views and interprets findings in studies both in the laboratory and in naturalistic settings involving clinical reasoning or other constructs. Take, for example, the physical location for the clinical reasoning event. If clinical reasoning is a trait (one truth), then variation in clinical reasoning from location to location would be unexpected and considered error, whereas if clinical reasoning is thought of as a state, then lack of variation from location to location could raise questions about the accuracy of the assessment of clinical reasoning.

Theoretical Viewpoints of Learning and Assessment

Our epistemological viewpoint largely determines the theoretical lens through which we view learning. Below are four common theories used by medical educators to understand learning (and, by extension, teaching and assessment).

Behaviorism

Behaviorism,[14] in its purest form, considers only behaviors (observable actions) as meaningful. A person with this theoretical perspective would thus consider clinical reasoning as incorporating only what can be *directly seen* in the clinical encounter. From the strict behaviorist viewpoint (Note: There is a continuum of behaviorist perspectives), the clinician's thought processes and emotional state would not be considered important parts of the reasoning process. Behaviorism argues that clinical reasoning is learned through behavioral modification; that is, we learn to reason on the basis of the contingent rewards and punishments we receive. Or, in an expanded view of behaviorism, we can also learn reasoning vicariously by watching others be rewarded and/or punished for their behaviors in clinical practice. Neobehaviorists, on the other hand, would view thoughts and emotional states, which result from prior experiences, as important aspects of an individual's behavior in relation to a stimulus.[15] Notably, however, these proponents would hold that thoughts and emotions are shaped by prior stimuli and are important only in that they can shape responses to future stimuli. The emphasis is on describing, modeling, and predicting *responses to stimuli*, not on *understanding* human thoughts and emotions. Thus, from this perspective, one's behavior (in response to a stimulus) leads to internalization of thoughts and feelings as a result of behavior, which influences subsequent responses to stimuli; thoughts and

feelings are not the origin of behavior but the response to behavior.

From the behaviorist perspective, learning, teaching, and assessment should entail observable actions because we are most interested in an individual's response to stimuli. In terms of research implications, this theoretical viewpoint would consider studying the workplace, its rewards and punishments, as paramount to describing, modeling, and predicting clinical reasoning. For example, a prominent behaviorist (Skinner) approached language development purely as a process of reward and punishment.[14] In rebuttal, Chomsky[15] (a neobehaviorist) noted that such a view could not account for our ability to produce sentences that we have never heard. In sum, *understanding* clinical reasoning is not a focus of the behaviorist perspective. Though not a prominent theoretical perspective in medical education today, components of the behaviorist theoretical perspective are evident in the focus on medical education outcomes (the behavior) and competency-based medical education, which often come at the expense of process measures. What is desired in these frameworks is displaying the "behavior" (competency), whereas understanding how one obtains the competency is not so much the focus. It is important to recognize that behaviorism emerged, in large part, from an objectivist epistemology, which we will return to in the next section.

Information processing theory

Information processing theory is a pervading perspective in medical education today. Theories that fall under information processing include, for example, script theory[7,8] and dual process theory.[5] In medicine, illness scripts can be thought of as incorporating all of the features that can be seen in a given diagnosis, as well as the range in presentation that can be seen and still be consistent with the illness (diagnosis).[7,8] Dual process theory argues that physicians use two general processes when approaching the task of clinical reasoning: analytic reasoning, whereby a physician actively compares and contrasts options (diagnostic or therapeutic) while deciding on the best option, and nonanalytic reasoning, which entails pattern recognition, or immediately recognizing the best option to take without actively comparing and contrasting options.[5] Analytic reasoning is effortful and believed to be slower than nonanalytic reasoning, which is believed to be effortless and immediate.[5] How scripts and these two processes (analytic and nonanalytic) interact is not fully understood. For example, what leads a physician to switch between analytic and nonanalytic reasoning? Or, instead, is clinical reasoning, broadly speaking, more of a continuum than an "either/or" phenomenon? Is analytic reasoning always effortful, or can it be so well practiced in an expert that it only seems effortless? How do various contextual factors affect reasoning? Even the process of pattern recognition (the fast process) is not a well-understood phenomenon.[6]

Cognitive load theory (CLT)[16] is another important, and more contemporary, information processing theory that some have used to help explain clinical reasoning.[17] CLT refers to limitations in our cognitive architecture and suggests that we can hold (or process) only a finite number of informational "chunks," or units, at a given time; the number of chunks is assumed to be no more than nine. CLT also specifies different types of cognitive load.[16] Further, CLT provides a hypothesis to explain how we overcome the limitations of our working memory by accessing long-term memory and using "chunks" of knowledge in working memory.[16]

Information processing theory became popular with the emergence of the computer, and this theory typically uses the computer metaphor: We store information in a symbolic fashion that is recalled later for accomplishing clinical reasoning tasks.[5,18] Unlike the behaviorist approach, information processing theory places greater value on a physician's mental processes (that are not observable); the emphasis is on *understanding* the construct (here, clinical reasoning) rather than coming up with a model to predict the observable behavior (behaviorist approach). One can see how these two theoretical viewpoints can conflict—understanding as opposed to observation and prediction.

From the information processing viewpoint, clinical reasoning can be defined as the *internal mental processes* (versus observable behaviors) that a physician uses when approaching clinical situations. Furthermore, as the emphasis is on mental processes, information processing theorists believe that clinical reasoning can be taught by giving trainees organized, incremental pieces of information and/or varying the individual pieces of information that lead to subsequent improved clinical reasoning performance. However, the emphasis on clinical reasoning as an internal mental process makes learning clinical reasoning challenging. That is, the emphasis is on acquisition of well-organized knowledge, although experience (through refining knowledge) also plays an important role in this viewpoint. However, from the information processing theorist's perspective, specific situational factors—the environment of the clinical encounter and the interactions between patients and physicians—are believed to be of less value.[18] These specific situational factors are largely seen as theory-unrelated and, therefore, are considered to be unwanted sources of variation (i.e., situational factors are artifacts of the measurement method and not the focus of study). In other words, information processing theory does not explicitly address the clinical context or the weighing of informational units or details that lead the physician to the diagnostic and treatment plan.

From an instructional perspective, the format of instruction does not need to be in a clinical setting, and indeed CLT would argue that, at least at first, this teaching should involve low-fidelity or low-authenticity methods (i.e., paper cases of basic components of the diagnosis or therapy). Additionally, CLT would argue for slow progression, where learners progress to more complex clinical presentations once they learn "the basics." Furthermore, extraneous load (that which is imposed by the teaching method itself) should be minimized as much as possible, with a focus on the intrinsic load (that which is related to the complexity of the content) that can lead to more learning effort (germane load). It has been argued from the CLT perspective that learning should start with well-defined problems, first in nonauthentic settings, and followed by gradual increases in the complexity of the problems (i.e., the authenticity of the learning environment). This theory places a priority on acquisition of knowledge and the notion that teachers should be content experts who primarily provide knowledge

structure and organization to trainees so that they can build their illness scripts.

From the information processing perspective, an oversimplified (but, we believe, useful) analogy to help the reader is the idea of "transferring or transporting" information from the mind of the expert into the mind of the trainee.[18] From this viewpoint, lectures could be a very useful approach to learning. Research implications entail studying the ways that information is presented so that it can be easily and efficiently encoded into memory and retrieved later. A medical education example might involve an objective structured clinical exam (OSCE) station pertaining to the oral presentation. From an information processing theory perspective, the emphasis would be on understanding the trainee's knowledge structures, and thus assessment and feedback would be directed toward knowledge construction and organization. From a behaviorist perspective, the emphasis would be on the behavior displayed and predicting performance in future iterations of the oral presentation, and therefore the emphasis for evaluation and feedback would be on the observable actions, with far less emphasis on understanding mental processes.

Generally speaking, both behaviorism and information processing theory (or cognitivism) fall under the umbrella of objectivist, or positivist, epistemology. The primary goal with both approaches is being able to communicate or transfer knowledge to learners in the most efficient and effective manner. One important key to efficiency and effectiveness is the notion that complex processes and ideas can be broken down, or simplified, into basic components that are agreed on by all involved. Such an approach would argue that effective instruction should remove extraneous information (potentially irrelevant information, including contextual complexities) to improve learning.

Psychometric theories

Although not traditionally thought of as theories of learning, psychometric theories pervade medical education and shape the way we view numerous topics, including clinical reasoning. These theories address the concept of clinical reasoning as a domain that can be measured in a reliable and valid way, where "reliability" refers to reproducibility and "validity" refers to the extent to which we measure what we intend to measure. Psychometric theories do not make any specific claims with respect to clinical reasoning (they are not learning theories, per se), and so what we discuss applies to any construct viewed through these theories.

From the psychometric perspective, we are attempting to measure a latent (unobservable) construct like clinical reasoning ability. From this perspective, there is an objective truth we are trying to capture (i.e., this is an objectivist, or positivist, epistemology). Many such theories view latent constructs like clinical reasoning as traits (versus states), and we have discussed this assumption previously. But, psychometric theories[19,20] do require the researcher to explicitly state the nature of the construct of interest and its characteristics, and they further require that the explication be done in a way in which the challenging of assumptions is possible. Kane[19] further explicates that the variability of the construct (in this case, clinical reasoning) may be an element of its nature and should not necessarily be seen as construct-irrelevant variance. Such psychometric views incorporate construct underrepresentation (i.e., small samples) and thus may require large samples to test hypotheses.

If reasoning cannot be captured in a reliable and valid manner, then the construct of reasoning is questionable or, at least, is in need of refinement. This is a view much like the behaviorist perspective—If you can't see or measure it, it probably is not relevant. Further, like behaviorism, the psychometric viewpoint puts emphasis on what is observable, but it goes even further, placing even more emphasis on what can be quantified, in a repeatable way, and used to predict future performance. From this perspective, it is not known whether reasoning can be measured (and, as an extension, learned, which is a topic of debate in the medical education literature today) unless the construct and outcome behavior can be clearly defined, both in a reliable and valid fashion. Assessments can be created once the construct is clearly defined, per the guidelines above. For psychometricians, research is focused on constructing reliable and valid scores using well-developed measurement tools, which may be used to teach and assess clinical reasoning. Returning to our oral presentation OSCE station example mentioned above, if the performance cannot be quantified in a reliable and valid fashion, this calls into question the construct being assessed.

Situativity theory

Situativity theory[18] argues that clinical reasoning is rooted in the specific situation (as does behaviorism). Two leading theories are situated cognition and ecological psychology.[18] Situated cognition argues that thinking (cognition or reasoning) is nested in experience, and to understand reasoning means to understand the particulars of the situation and experience. Ecological psychology proposes that reasoning is the result of a goal-driven person interacting in an information-rich environment. In both of these theories, the environment, or practice setting, and the interactions between the physician, the patient, and the health care team are critical. This assumption represents one departure from the above-stated theories. That is to say, from a situated perspective, the environment and the interaction are seen as part of the measurement phenomenon, or true variance, as opposed to noise or measurement error. The physician is responsible for the final diagnosis and therapy, but she or he is influenced meaningfully by these other factors (environment and participants). Clinical reasoning, from a situativity perspective, entails consideration for all the factors specific to the patient, the physician, and the encounter or practice setting, as well as their interactions. From this viewpoint, clinical reasoning represents all that occurs in the clinical encounter that specifically pertains to the diagnosis and therapy of the patient. Furthermore, situativity theory would argue that clinical reasoning is likely nonlinear, and thus our statistical methods to measure and compare clinical reasoning may not fully capture the variance in this construct. And whereas other theories may acknowledge nonlinearity as a possibility, situativity theory proposes that nonlinearity is the most likely model.[18] From a situated perspective, linearity is likely to occur only in straightforward presentations, typical diseases, and/or inauthentic laboratory (study) settings.[18]

In terms of instruction, situativity theories stress the need for workplace

assessment. Teaching should also emphasize authentic instructional formats. Assessments should include the views of all participants in the encounter and the setting. These theories would agree that behaviors and information processing (i.e., scripts, dual process, and cognitive load) are all part of clinical reasoning but that, separately, they represent an incomplete description for all but the most straightforward cases.

Practical Implications and Future Directions

When we consider the epistemological and theoretical lens through which we view clinical reasoning, important assumptions, challenges, and implications emerge for learning, teaching, and assessment. Furthermore, by considering other theoretical frameworks, additional questions and potential solutions come to light that were not apparent when we consider only a single theoretical lens. It may be that certain theoretical frameworks make more sense depending on the specifics of a given clinical situation, and so we believe that flexibility in one's approach is warranted. Thus, it is important to recognize, as Alfred Korzybski famously stated, that "the map is not the territory."[21(p190)] That is, just as no single map can completely and accurately represent the physical terrain it depicts, no single theory of learning (or reasoning) can fully and accurately represent the underlying mechanisms of complex cognitive processes. As abstractions, theories, by their very nature, are simplified versions of some more complicated (and not fully understood) phenomenon. What is more, it is important that we do not confuse maps with territories—that is, that we do not confuse our theoretical models of reality with reality itself. Instead, we should acknowledge that each theory provides a different way of viewing reality and, as such, enlightens us about different aspects of what is actually happening. We therefore would argue that theories are inherently constructivist in nature.

Multiple Perspectives: Toward a More Unified Clinical Reasoning Theory

We believe that clinical reasoning encompasses both the mental processes as well as the behavior exhibited in terms of diagnostic and therapeutic decisions and that the mental processes and behavior are shared (or evolve) between the patient, physician, and environment. Clinical reasoning thus incorporates components of information processing, behaviorism, and situativity, respectively. We need to approach the topic with the precision that psychometric theory provides, but additional considerations, outlined below, need also to be incorporated. Thus, a new perspective toward clinical reasoning is needed to advance the field.

Each of the clinical reasoning theories discussed above poses important challenges and has important limitations. Each has helped move our understanding of clinical reasoning forward. Clearly, none of these theories is sufficient alone, and thus we propose a model that explicitly incorporates elements of all the theories to help us move our understanding forward. The model (illustrated in Figure 1), which combines a variety of clinical reasoning theories should be tested empirically to see whether the model is sufficient and advances our understanding and prediction capabilities. Further, we believe that the theories reviewed above are particularly incomplete when addressing the early clinical learner. For example, behaviorism's focus on only what can be directly seen in the clinical encounter, largely ignoring thought processes and emotional states, excludes important features of clinical reasoning. Behaviorism is identified as "experience" in Figure 1.

Information processing theory was developed largely from the study and understanding of experts; we believe that it falls short in explaining what may be going on in the more junior learner. With its focus on knowledge and its organization in the physician, it also does not efficiently take context into account. We believe that the information processing theories represent important physician factors (i.e., dual process and script theory) and interaction between physician and patient (cognitive load, which also represents a physician factor). The model also helps explain how scripts are activated as well as the processes influencing the trainee's sensitivity to information (CLT). Information processing theory is identified as knowledge and cognitive load in the "physician factors" circle of Figure 1.

Psychometric theory focuses on the need for precision in measuring the construct of clinical reasoning. Indeed, we believe that medical educators should strive to improve the measurement precision (reliability and validity) of the components or factors underlying our model (physician, patient, and environment); however, by solely focusing on one of these factors, much is lost in what is actually going on during a real clinical encounter (reasoning as one example of a construct to be

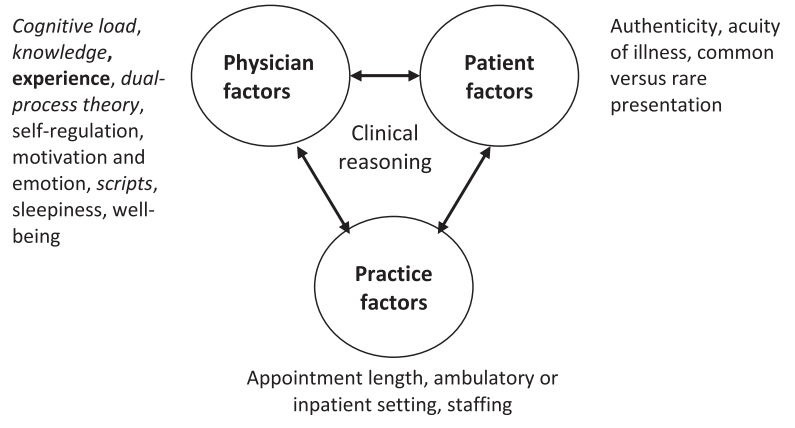

Figure 1 One's definition of clinical reasoning is founded on which theoretical viewpoint one uses, consciously or unconsciously. Awareness of this approach allows one to compare different definitions of what clinical reasoning may entail as well as to compare practical and teaching implications. The figure illustrates different clinical reasoning viewpoints: behaviorism (indicated by the bolded word "experience"), situated cognition (indicated by the circles and arrows), information processing theories (indicated by the italicized words), and a focus on reliability and validity of the terms next to each of the three "factors" circles. See the article for full descriptions of these viewpoints. The bidirectional arrows are driven by factors such as cognitive load and balancing of goals.

assessed). Attention to reliable and valid measures of each of the component parts is represented in Figure 1 by the three connected circles.

We believe that situativity theories provide a useful overarching view of clinical reasoning. These theories bring a social perspective to clinical reasoning and outline factors specific to the physician, patient, and setting (and their interactions), which gives us a more inclusive view of what is occurring in terms of clinical reasoning (i.e., an important additional way of viewing the "territory"). But these theories do not specify the "component parts" of each of these three factors, let alone what drives the interactions (bidirectional arrows in the figure). The other theories can help determine or shape the specific factors. In the explanatory text adjacent to the figure's circles, we have included examples from behaviorism, information processing, psychometrics, and other theories and conceptual frameworks.

An important implication expressed in the figure is the notion of *nonlinearity*. As the individual components underlying each factor can interact in dynamic ways, our current models for assessing clinical reasoning often fall short of what is actually occurring. Currently, psychometrics focus on linearity, or the idea that the outcome should be the result of a single chain of consecutive events. We believe that the figure makes it apparent that clinical reasoning (like many other constructs) entails the interaction of discourse with a patient in an environment and that understanding leading to diagnosis and therapy evolves from and entails interaction of potentially a large number of component parts (we have listed only some of the potential mix of interacting components underlying each factor). All of the preceding theories, with the exception of situativity, would argue against the possibility of nonlinearity. This does not mean that every clinical encounter will proceed nonlinearly but only that the phenomenon of clinical reasoning possesses nonlinear attributes, which may be apparent in many encounters.

Linearity and nonlinearity: A metaphor of driving a car

A metaphor to illuminate the differences between linearity and nonlinearity is driving a car. We believe this is particularly useful given the recent discourse on this point in recent publications.[22,23] A traffic jam represents a nonlinear event; that is, the movements (or lack thereof) of individual cars in a traffic jam can have nonadditive (and indeed profound) effects on the flow of traffic (to include accidents). A driver in a traffic jam must pay close attention to component parts (i.e., the other cars) to successfully navigate the jam. This is unlike driving one's car down a highway without any traffic, which is a metaphor for a linear event or a carefully structured laboratory experiment. Then, of course, there are the "in-between" situations (varying degrees of traffic), which can be linear or potentially nonlinear. Certainly, one's driving skills in linear events are also important in nonlinear situations; however, the skills in the former situation (linear driving event) do not necessarily account for all that is needed in the latter (nonlinear driving event). One can successfully drive with drowsiness, a blaring radio, and/or a loud conversation when there is no traffic; it is far more difficult to successfully navigate under these circumstances in a traffic jam. We believe that our integrative figure and inclusive theory illuminate these features for the practice of medicine.

Implications

We would argue that education and assessment should focus less on the single best route through an encounter and focus more on the context as well as the "boundaries" or range of acceptable performance in an encounter. The difference between an expert and a nonexpert from this perspective is that the nonexpert's performance may not fall into one of several "trajectories" of acceptable performance. In contrast to psychometric, information processing, and behaviorist perspectives, there is not one "true" or correct path to the answer; there are *often* multiple, equally acceptable paths. What defines expertise is performance within a set of boundary conditions. Our theoretical framework (Figure 1) encompasses this approach.

Implications for learning entail focusing on the context and component parts. An example of this is self-regulated learning theory, a triadic, reciprocal loop that encompasses activities undertaken before engaging in a task, activities while engaging in a task, and reflection during or after engaging in a task. The specific activities in these three domains are dependent on the context of the activity, which includes the environment and the participants. Importantly, training in multiple phases results in large improvements in performance, and analysis of this nonlinear model could result in explaining the majority of the variance in the outcome with incorporating measures from each domain.

Further educational implications of this model include focusing more on the participants and the environment. Our model would place a much greater emphasis on the importance of teamwork, interdisciplinary education, and the patient's perspective. Such an approach also stresses how information other than the content or "script" of the diagnosis can affect decision making for good or ill. Indeed, research is emerging that supports the importance of contextual factors on experts' reasoning.[16,24]

Challenges to the model include the potential for nonlinearity. Fortunately, experts in this field have demonstrated that understanding complexity and complex systems can be straightforward, as the interactions can be understood by looking at the problem from a broader view and considering first- and second-level interactions as opposed to trying to explore all potential interactions. Clearly, new quantitative methods are needed to demonstrate numerically the existence of nonlinearity. Fortunately, such models exist,[25] and in situations similar to those of medicine, these models explain more of the variance in the outcome of interest than do linear methods.[25] Qualitative methods and mixed methods can be particularly illuminating of the existence of nonlinearity and could be used to inform/revise the framework we present. Indeed, mixed methodology probably represents the best way to test or demonstrate that our theoretical framework reflects actual practice.

As a final metaphor, take a major league baseball player who can consistently throw strikes (the strike zone represents the boundaries) but for whom throwing the ball in exactly the same location from one pitch to the next is not desirable (or possible). We believe such

a perspective is particularly helpful in naturalistic settings (such as the clinical encounter), where so many variables can, and often do, interact. In such settings, predicting or observing for a static behavior (behaviorist and psychometric theoretical perspectives) or for understanding what is going on in a physician's mind without taking into account the environment or interactions (information processing theory) is likely to be not very fruitful.

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