Review

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Situativity: a family of social cognitive theories for understanding clinical reasoning and diagnostic error

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Abstract: The diagnostic error crisis suggests a shift in how we view clinical reasoning and may be vital for transforming how we view clinical encounters. Building upon the literature, we propose clinical reasoning and error are context-specific and proceed to advance a family of theories that represent a model outlining the complex interplay of physician, patient, and environmental factors driving clinical reasoning and error. These contemporary social cognitive theories (i.e. embedded cognition, ecological psychology, situated cognition, and distributed cognition) can emphasize the dynamic interactions occurring amongst participants in particular settings. The situational determinants that contribute to diagnostic error are also explored.

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Introduction

From a holistic perspective, clinical reasoning can be defined as an amalgam of evolving psychological processes, behaviors, and social/physical environmental factors that may shift across contexts (situations); this amalgam is co-constructed by the physician and patient [1]. Clinical reasoning includes accurately assessing and prioritizing most probable diagnoses, while considering consequences, treatment alternatives, and comorbid illnesses, as well as available resources [2]. When clinical reasoning goes awry – whether for individual, social, or environmental reasons – diagnostic error can occur. Diagnostic error is a world-wide crisis with detrimental – and potentially devastating – impact on patient care [3–6]. Thus, strengthening clinical reasoning abilities in order to reduce diagnostic error in medicine is crucial [7].

The construct of clinical reasoning is not monolithic, however, and there exist diverging conceptualizations of the components and processes that comprise it [1]. The complexity of clinical reasoning is reflected in these disparate perspectives, which range from a more classical approach centered on the dual process theory (non-analytic and analytic reasoning) to broad social perspectives entailing a larger awareness of environmental and contextual factors [1, 8–10]. The classical conceptual landscape dominating diagnostic error and clinical reasoning research was derived from cognitivism or the information-processing theory [7, 11, 12]. Moving beyond the boundaries of these lenses, the health professions education literature is now exploring the role that failure to acknowledge situational determinants contributes to diagnostic error, and the use of social theory to inform

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both clinical reasoning and diagnostic error research. This special edition explores a family of social cognitive theories and how they can inform our understanding of clinical reasoning and, by extension, diagnostic error.

Situativity theories

This family of social cognitive theories, often placed under the umbrella of *situativity* [7], contrasts with the information-processing theory. This family of theories takes into account how the physican's clinical reasoning (whether successful or leading to error) is shaped, beyond individual beliefs and knowledge, by others present during the encounter, the multiple environmental inputs, and their interactions. Traditional information-processing theories focus on those elements of cognition occurring in the individual's mind and typically treat everything else as *noise* [13]. Conversely, the family of social cognitive theories, often placed under the umbrella of situativity, moves beyond individual beliefs and knowledge construction to consider those present during the encounter (e.g. the patient and his/her family members, other health care workers, learners), the multiple environmental inputs (e.g. appointment length, artifacts such as electronic health record functionality, culture), and their dynamic interactions. Said differently, the unit of analysis shifts from the individual physician to the other participants, the setting, and the interactions that occur [7]. Seen from this perspective, clinical reasoning is not limited to the provider and rather depends on the complex interactions among a variety of provider factors, patient factors, and encounter/practice factors [7], which are also referred to as "contextual factors". This family of theories provides a model – a way to explore the role that these various inputs may have on clinical reasoning with a view to helping to advance teaching, assessment, and research in the field.

This overview has three objectives. First, we introduce four individual members of this family of social cognitive theories, describing their unique elements in relation to clinical reasoning and error. These theories – (1) situated cognition, (2) distributed cognition, (3) embodied cognition, and (4) ecological psychology – are distinct, yet complementary, lenses with which to view a clinical situation. Next, we contrast these theories, summarizing the focus of each theory and finally we highlight the potential role of nonlinear conditions that can have an impact on clinical encounters.

Situativity theories have the capacity to accentuate important features of a situation that may be overlooked, creating a more comprehensive and holistic conceptual framework. They share, to a greater or lesser degree, the "three Es": the *embodied* mind (how the mind interacts with the body), the *embedded* mind (how the mind is embedded within the environment), and the *extended* mind (how the mind interacts with the universe of other conditions and factors that are active within a given environment and context) [14]. The *embodied* mind refers to how the body can shape the mind. For example, using a stethoscope to detect a heart murmur in a patient involves positioning the stethoscope, hearing the abnormal sound, and interpreting the findings in the context of the patient's presentation. In other words, a physical examination conducted by a provider consists of motor actions guided by "cognition". This concept of the embodied mind can also apply to the use of an ultrasound, catheter, ventilator, and any other environmental support (also known as *artifacts* in the theory literature) in clinical medicine.

The *embedded* mind refers to the notion that our thinking interacts with the environment. For example, we can "off-load" cognitive work onto our cell phone by looking up specifics on a drug or condition while rounding in the hospital. The *extended* mind claims that the boundaries of our reasoning lie outside the envelope of the individual, encompassing features of the physical and social environment. This is the idea that reasoning is distributed across individuals and situations (e.g. playing a team sport or Scrabble, or rounding with a ward team). Another example – team-based competency – includes a collaborative effort of knowledge, skills, and attitudes, as an important strategy to enhance diagnostic quality [15]. As such, developing effective proximal (or "primary") teams (e.g. physician, physician assistant, nursing staff) and distal (or "specialty") teams (e.g. pathologists, radiologists, allied health professionals) has become an important recommendation for improving diagnostic performance [16].

In addition, shifting from viewing the physician as an individual agent to one who makes decisions in the context of, and is influenced by, the physical and social environment, can transform our approach to diagnosis and error, and for opening up new perspectives. Clearly, new perspectives are needed given the diagnostic error crisis. This is not, however, to diminish the agency of the physician in making the diagnosis and creating a management plan specific to a patient's circumstances and preferences, but rather recognizes that clinical reasoning is often powerfully shaped by the physician's interactions with other participants, the larger community, geographical features of the environment, and an array of dynamic interactions across all of these factors.

Embodied cognition

Embodied cognition is a theory with the premise that the body is a necessary "constituent" of cognition [17, 18] and that higher-level mental constructs, such as clinical reasoning, depend on perceptual and motor systems (i.e. the embodied mind). Embodied cognition emerged from computer science and more recently, artificial intelligence fields. Kay and McDaniel suggested in 1978 that the perception of color requires both complex internal and external processing [19]. This perception deviated from the dominant paradigm of disembodied cognition. Several years later, Mervis and Rosch found that delineating basic-level categories (e.g. a table which can have a variety of shapes and sizes) requires both neurological and bodily functions [20]. This literature led to the view that *both* the actions performed by the body as well as the abstract concepts typically associated with the mind are embodied [21]. Embodied cognition focuses on the physical characteristics and innate capabilities of an organism's interaction in the environment [22]. Cognition is believed to be distributed across the mind, body, and environment, and is essential for action, whether directly at a specific time (when the body interacts within the environment), or indirectly (when information is stored for future actions) [23].

Moreover, embodied cognition posits that the body is not simply a vessel for the mind, where cognition really occurs, but that the sensory and motor inputs are critical for cognition. This school of thought would thus argue that an understanding of neuroscience is important for educators. Embodied cognition can be considered in two forms – online and offline. While online embodiment refers to the direct impact of the sensorimotor encounter with the environment on cognition, offline embodiment has been described by Ignatow as the "continuing influence of this repertoire of bodily responses even when cognitive activity is decoupled from the social and physical environment" [24]. One such clinical example includes reflecting on a patient that you saw the prior day and taking action the next morning. Through this lens, clinical reasoning and mitigation of error requires hands-on, eyes-on experiences that, over time, are cataloged for retrieval as needed. From this view, insufficient or incorrect sensory and motor inputs from past or current situations could contribute to diagnostic error. For example, consider an older physician, with some hearing impairment, mischaracterizing a heart murmur in a noisy emergency department which leads to error caused by limited sensory resources. Applying the view of embodied cognition to surgical performance, for example, holds that "experience-induced improvements in the perception of and response to possible situations in the environment are key" [25]. Similarly, in obstetrics, sensory and motor experiences over time are critical to be able to diagnose and intervene in complications during labor. For example, fetal malposition is a situation that can be addressed with successful delivery of a healthy baby by the appropriate route (vaginal or cesarean delivery), if the situation is correctly identified and diagnosed. Fetal malposition cannot be diagnosed or addressed without a rich repertoire of sensory and motor resources. Another illustration of diagnostic error caused by limited sensory/motor resources is a younger physician who misses the presence of a pleural effusion in a patient with community-acquired pneumonia due to poor percussion technique and a noisy ward setting.

Ecological psychology

Ecological psychology emphasizes that learning and performance happen when goal-driven and able participants interact with their environment. According to Young, ecological psychology (which has been informed by biology and physics) emerged from the philosophical traditions of rationalism and empiricism; and cognitive activity therein is depicted as being drawn from sensory information in a human-environment exchange [26]. The emphasis in ecological psychology is on the participant, interacting with an inherently complex environment [27]. Four main concepts have been employed to describe learning and performance within the ecological psychology approach: (1) *affordances* – the properties of the environment that are opportunities for learning and performance; (2) *effectivities* – the ability of the participant to take action on those opportunities; (3) *intention* – the participant's goals which are dynamic and may evolve; and (4) *attention* – the tuning of the participant's perception to detect opportunities in the environment. The interactions between the dyads of affordances and effectivities, and intention and attention (deliberate engagement such as is required in a game of Scrabble, sports, or in the operating room) are key to learning and performance. Affordances describe the possibilities of action in an environment and differ in their availability to different participants according to their effectivities. Affordances are also dependent upon the intention of the participants – these are specific to the individual. Effectivities, which also involve attentions, direct how participants capitalize on affordances, which drives their attention or their ability to detect what affordances are available to them. For example, a door knob is turnable (affordance), but only if one has the capacity to view and reach it (effectivity); one could argue the same for a stethoscope, a functional magnetic resonance imaging (fMRI) scanner, or a scalpel. Considering the implications for diagnostic decisions from an ecological psychology perspective, McBee et al. highlighted that affordances and effectivities vary according to specific features of clinical cases and impact diagnostic decisions [28]. The specifics of the clinical situation clearly matter, but a nuanced understanding of the interaction between the participants and their environment is equally relevant. As such, physicians must be cognizant of the specifics of a case, their intentions, and the environment to clinically reason well and avoid error. From an ecological psychology perspective, it is also impossible to separate the participant, the content, and the environment.

Situated cognition

Situated cognition embraces the tenets of embodied cognition as well as the importance of interactions emphasized by ecological psychology. Situated cognition argues that thinking, in this case clinical reasoning, is situated (or located) in the specifics of the circumstances. Situated cognition recognizes the dynamic sources and interplay of such sources of information in specific situations. In the twentieth century, deviating from the traditions that privileged isolated cognition, Dewey (among others) argued that “In actual experience, there is never any such isolated singular object or event; an object or event is always a special part, phase, or aspect, of an environing experienced world – a situation” (p. 67) [29]. Work in situated cognition was later advanced by Greeno and others [30–32]. Situated cognition constitutes a dynamic interplay between internal and external sources in specific situations [33]. Applying this to a clinical setting, consider the physician who, given ample time and diagnostic information in a patient who presents in a typical fashion, may consistently correctly diagnose and treat an acute cardiac syndrome. The same physician, however, may err when confronted with an atypical presentation (e.g. dyspnea vs. chest pain), pressed for time, and an electronic health record system that is improperly functioning to affect the provider’s performance. This exemplifies how various patient and practice factors accumulate to affect physician clinical reasoning leading to error.

Distributed cognition

Distributed cognition is best conceptualized as an approach that recognizes cognitive processes are distributed across many individuals, artifacts, and tools in the environment [34]. Like situated cognition, distributed cognition embraces tenets of embodied cognition and ecological psychology. It is similar to situated cognition, but can account for a large number of individual and environmental inputs that can shape thinking. In distributed cognition, emphasis is placed on how reasoning emerges from multiple participants – an idea which evolved from ethnographic studies of navigation processes aboard Navy vessels [34]. In *Cognition in the Wild*, Edwin Hutchins describes cognition as being distributed across not only individual members of the navigation team, but also across nautical charts, written protocols and checklists, depth-finders, radar, sonar, binoculars, compasses, and many other artifacts [34]. In addition, when considering the ancient inhabitants of Micronesia, who used careful observations of stars, ocean color, and wave patterns to navigate accurately across vast distances in the open sea, Hutchins includes the natural world as an essential component of distributed cognition [34]. Here again, cognition has been delineated as socially distributed across participants (e.g. teams) and artifacts, and accounts for the contribution of the environment [35]. Later, Cohen and others emphasized that the key concept in this perspective is that cognition (in this case reasoning and error) is extended – it is not a phenomenon which occurs *inside* an individual, but rather *outside*, across the breadth of the social (e.g. multiple individuals) and the environmental context [36].

Distributed cognition continues to attract attention in several areas of health professions education – most notably in understanding, detecting, and mitigating (or preventing) errors, and in the development of systems of artificial intelligence. In 2006, Cohen and colleagues used the idea of distributed cognition as a lens through which to understand collaborative processes in a psychiatric emergency department (ED), and to explore the phenomenon of medical error [36]. In their paper, they described the case of a patient who was being evaluated in an ED, and who was noted to have an active prescription for lamotrigine, 200 mg twice daily. When the patient was admitted to the inpatient ward, an order was written for lamotrigine, 1200 twice daily. This erroneous dose may have been written on the ED “white board” (the central shared representation, critical in communicating and coordinating care in the ED) – though this was not confirmed. Distributed cognition emphasizes the need to seek information distributed across patients, physicians, nurses, artifacts, and the environment, to conform to the congruence of data coming from these distinct sources, and to recognize inconsistencies in the data as a strong signal of possible error. In this way, the health professional team takes on combined responsibility in clinical reasoning to improve patient outcomes.

Overall, looking at this family of theories more specifically, embodied cognition focuses on how sensory and motor inputs significantly have an impact on cognition [33, 37]. Ecological psychology emphasizes interactions between participants and the environment (e.g. affordances and effectivities). Situated cognition stresses that individuals and environmental artifacts play an important role in cognition in groups of limited size (e.g. five or less). Finally, distributed cognition highlights that – external to the individual – cognitive events can occur across multiple actors (e.g. larger groups and/or evolving over time). Taken together, this family of theories characterizes clinical reasoning as embedded in a specific situation; meaningful interpretation is derived by heightening one's awareness of the complex interdependent interactions among individuals, the (physical and social) environment, and is unearthed through goal-directed behavior [7]. In effect, external factors are active, and have the capacity to interfere with, assist, and govern physician behavior [33]. Taken together, Figure 1 provides a depiction of this family of social cognitive theories for improving clinical reasoning and reducing diagnostic error.

The following clinical scenario and the Table 1 provide a basic depiction of specific elements highlighted by each theory:

A 70-year-old woman presents to the emergency department following a motor vehicle accident. She is short of breath and the clinician – recognizing the acuity of the patient's presentation – notifies the nurse to have her evaluated immediately. Her vitals are notable for

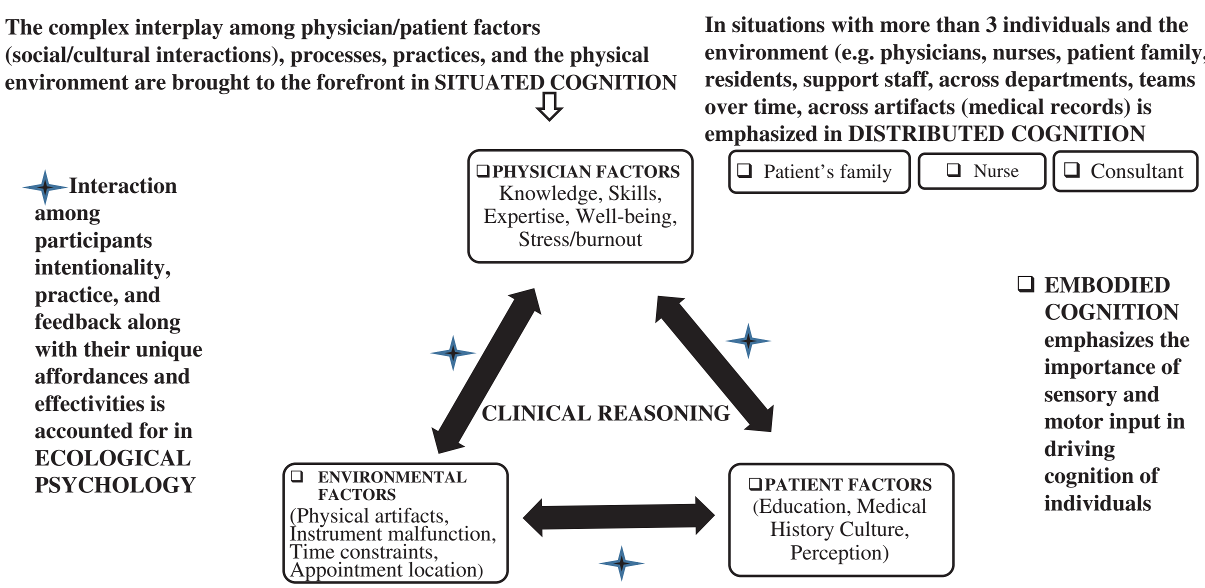

Figure 1: Combining a family of social cognitive theories for improving clinical reasoning and reducing error.

Table 1: Clinical scenarios that depict each theory.

Theory	Evidence
Embodied cognition	Performing and interpreting chest percussion, recognizing hyper-resonance and absent breath sounds using one's hands and the stethoscope
Ecological psychology	Recognizing tension pneumothorax (affordance) and acting to use a needle from the crash cart to treat the patient (effectivity). One would not expect a medical student to either recognize the affordance or (even less likely) to use a needle from the crash cart (effectivity)
Situated cognition	Recognition of patient presentation (history and PE) and environmental factors (crash cart), and acting appropriately
Distributed cognition	Clinician, recognizing the acuity of the patient's condition, transporting her urgently from the waiting room, and notifying the nurse. Nurse, recognizing the critical situation, obtaining the crash cart

hypotension, tachycardia, and hypoxemia – her oxygen saturation is 84% on 6l NC O2. The physical examination is notable for tracheal deviation, chest contusions, hyperresonant chest percussion, and absent breath sounds over the left lung field. The charge nurse – recognizing the patient's distress – gets the crash cart. The clinician opens the cart and finds a needle that she inserts into the patient's left thorax with improvement in symptoms, vital signs, and oxygenation.

Discussion

This family of social cognitive theories – embedded cognition, ecological psychology, situated cognition, and distributed cognition – bring to the forefront the embodied, embedded, and extended mind and incorporate the elements of the clinical situation and the larger systems that can drive clinical reasoning and error. Key tenets of this family of social cognitive theories acknowledge that individuals rely on the physical and social environment. In this regard, clinical reasoning (and error) is seen as a state (i.e. is situationally determined) as opposed to being a trait (i.e. is inherent to the individual physician). This has implications for our understanding of the phenomenon of clinical reasoning and the errors which may occur.

Clinical reasoning is not "quarantined" in the decision-maker's head, rather the use of physical and environmental factors can be employed to bolster clinical reasoning and mitigate error. We believe that these so-called contextual factors may be even more important in cases of uncertainty or ambiguity. The ability to detect these factors and their interactions residing within a specific situation has implications for teaching and assessment that we will discuss in a subsequent paper in this special edition.

This family of theories offer several strengths. Perhaps most evident is their ability to view the entire situation, regardless of its complexity, providing better understanding of nuanced situations such as context specificity. The concepts of the embodied, embedded, and extended mind open opportunities for studying, teaching, and assessing clinical reasoning that are otherwise considered noise in more traditional models (e.g. features in the environment and their interactions with participants). Finally, these theories also include environmental factors such as time and artifacts (e.g. the electronic health record) that are not explicitly included in traditional models. In sum, claims of this family of theories include the following six tenets (adapted from Wilson [23]):

1) Clinical reasoning is situated – it takes place in the real-world environment and inherently involves perception, action, and sensorimotor inputs.
2) Clinical reasoning is often time pressured – cognition really must be understood in terms of how it functions under real-world limits and interactions with the environment.
3) The environment is itself a component of clinical reasoning – the information flow between the mind and the world is so dense and continuous that one can argue that the mind alone is not a meaningful unit of analysis.
4) We off-load cognitive work onto the environment – often driven by the limitations of human cognitive architecture – and we can shape the environment to hold and even process information for us to harvest this as needed.
5) Clinical reasoning is for action – the function of the mind is to guide our action and it is closely tied to our body and the environment.
6) Off-line clinical reasoning is situation dependent – even when we decouple thinking from the environment, the activity of the mind is grounded in prior interactions with the environment that include our sensory and motor control.These theories also emphasize the unique aspects of individual situations that can illuminate clinical reasoning and error depending upon the teacher, assessor, or researcher's area of interest or focus. Embodied cognition emphasizes the importance of sensory and motor input in clinical reasoning and raises questions about investigations whereby explicitly (or implicitly) we limit these inputs, for instance, in relation to the clinical reasoning process (e.g. sitting at a desk using paper and pencil or even simulation and its impact on clinical reasoning and error). Ecological psychology emphasizes the interactions between participants and the environment including: intentionality, practice, and feedback; these can underpin clinical reasoning and error, the cognitive challenges of balancing multiple goals in a given encounter, and how some may be able to use key artifacts (e.g. in an emergency or operating room) and others may not (affordances and effectivities). Situated cognition perhaps provides the most portable framework for how to view clinical reasoning and error among a small number of individuals (e.g. patient and a clinician) and the factors involved [7]. Distributed cognition emphasizes how cognition can be stretched across a wider system and can provide a useful lens for exploring team-based diagnosis, handoffs, and ward team interactions.

While these theories propose ways of viewing clinical reasoning and error, we do not believe that any theory (or family of theories for that matter) represents the best approach. Instead, the choice of theory should depend upon the situation – the problem, the area of interest, or the research question. Information-processing theories are powerful and have been (and will continue to be) used to advance our understanding of clinical reasoning and error; we do not suggest that the teacher, assessor, and researcher abandon these approaches. Rather, we propose that this family of theories offers additional ways to view clinical reasoning and error situations that are complex and often “messy”. In fact, nonlinear dynamics dominate medicine [38]. Thus, helping physicians develop heightened sensitivity to patients and their specific contexts, while anticipating the unpredictable, can help promote more accurate diagnosis and healthy management of nonlinear patient and environment behaviors. However, this can only begin by approaching medical problems through a situativity-driven nonlinear lens.

While the key tenets of this family of social cognitive theories provide important perspectives and are useful for understanding messy and complex clinical scenarios, they often do not provide strategic intervention options. This is because they are “macro-theories”: theories which are large in scope, and are particularly useful for understanding complex systems and phenomena, and to illuminate productive or counterproductive reasoning processes [39]. In other words, macro-theories allow us to look at reasoning and error as a system, taking into consideration all participants, the environment, and the interactions, as opposed to an activity restricted to the individual and isolated decision-maker. Thus, this family of theories can help clinicians, researchers, and policy makers become aware of new structures, dynamics, and dimensions present in each unique clinical situation, as health care providers interact with patients in real time.

We propose such an alternative is crucial for reducing error and helping enhance clinical reasoning. For example, smaller-scale “micro-theories” can be used to complement these macro-theories to enable more specific action (see Samuel and colleagues’ discussion of macro- and micro-theories for more information [39]).

We believe that this family of theories represents a model that has important implications for frontline faculty, and we outline this in more detail in the next paper in this edition. Recognition of the importance of the environment on clinician performance can facilitate system-wide changes to improve diagnosis and management in healthcare systems. Moreover, the locus is not placed on the individual physician who may have erred, but rather how the system as a whole contributes to specific outcomes in patient care. Such theories also suggest that the environment should not be ignored in teaching and assessment, and that enhancing patient educational materials may go a long way to improving health care.

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References

1. Durning SJ, Artino Jr AR, Schuwirth L, van der Vleuten C. Clarifying assumptions to enhance our understanding and assessment of clinical reasoning. Acad Med 2013;88:442–8.
2. Juma S, Goldszmidt M. What physicians reason about during admission case review. Adv Heal Sci Educ 2017;22:691–711.
3. Donaldson MS, Corrigan JM, Kohn LT. To err is human: building a safer health system. Committee on quality health care in america, U.S. Institute of medicine. Washington, DC: National Academies Press, 2000.
4. Laureys S, Fins JJ. Are we equal in death?: avoiding diagnostic error in brain death. Neurology 2008;70:e14–5.
5. Sevdalis N, Jacklin R, Arora S, Vincent CA, Thomson RG. Diagnostic error in a national incident reporting system in the UK. J Eval Clin Pract 2010;16:1276–81.
6. National Academies of Sciences and Medicine E. Improving diagnosis in health care. In: Balogh EP, Miller BT, Ball JR, editors. Washington, DC: National Academies Press, 2015. doi:10.17226/21794.
7. Durning S, Artino Jr AR, Pangaro L, van der Vleuten CP, Schuwirth L. Context and clinical reasoning: understanding the perspective of the expert’s voice. Med Educ 2011;45:927–38.
8. Deschênes MF, Charlin B, Gagnon R, Goudreau J. Use of a script concordance test to assess development of clinical reasoning in nursing students. J Nurs Educ 2011;50:381–7.
9. Lee A, Joynt GM, Lee AK, Ho AM, Groves M, Vlantis AC, et al. Using illness scripts to teach clinical reasoning skills to medical students. Fam Med 2010;42:255–61.
10. Nouh T, Boutros M, Gagnon R, Reid S, Leslie K, Pace D, et al. The script concordance test as a measure of clinical reasoning: a national validation study. Am J Surg 2012;203:530–4.
11. Elstein AS, Schwarz A. Clinical problem solving and diagnostic decision making: selective review of the cognitive literature. Br Med J 2002;324:729–32.

12. Loftus S, Smith M. A history of clinical reasoning research. Clin Reason Heal Prof 2008:205–212.
13. Kirshner D, Whitson JA. Situated cognition: social, semiotic, and psychological perspectives. Mahwah, NJ: Lawrence, Erlbaum Associates, 1997.
14. Robbins P, Aydede M. A short primer on situated cognition. Cambridge Handb Situated Cogn 2009:3–10.
15. Olson A, Rencic J, Cosby K, Rusz D, Papa F, Croskerry P, et al. Competencies for improving diagnosis: an interprofessional framework for education and training in health care. Diagnosis 2019;6:335–41.
16. Graber ML, Rusz D, Jones ML, Farm-Franks D, Jones B, Cyr Gluck J, et al. The new diagnostic team. Diagnosis 2017;4:225–38.
17. Shapiro L. The embodied cognition research programme. Philos Compass 2007;2:338–46.
18. Leitan ND, Chaffey L. Embodied Cognition and its applications: a brief review. Sensoria A J Mind, Brain Cult 2014;10:3–10.
19. Kay P, McDaniel CK. The linguistic significance of the meanings of basic color terms. Language (Baltim) 1978:610–46.
20. Mervis CB, Rosch E. Categorization of natural objects. Annu Rev Psychol 1981;32:89–115.
21. Lakoff G. Explaining embodied cognition results. Top Cogn Sci 2012;4:773–85.
22. Anderson ML. Embodied cognition: a field guide. Artif Intell 2003;149:91–130.
23. Wilson M. Six views of embodied cognition. Psychon Bull Rev 2002;9:625–36.
24. Ignatow G. Theories of embodied knowledge: new directions for cultural and cognitive sociology? J Theory Soc Behav 2007;37:115–35.
25. van der Schaaf M, Bakker A, ten Cate O. When I say… embodied cognition. Med Educ 2019;53:219.
26. Young M. An ecological psychology of instructional design: learning and thinking by perceiving–acting systems. In: Handbook of Research on Educational Communications and Technology. Mahwah, NJ: Erlbaum, 2004:169–77.
27. Young MF, Barab SA, Garrett S. Agent as detector: an ecological psychology perspective on learning by perceiving-acting systems. Theor Found Learn Environ 2000:147–73.
28. McBee E, Ratcliffe T, Goldszmidt M, Schuwirth L, Picho K, Artino AR, et al. Clinical reasoning tasks and resident physicians: what do they reason about? Acad Med 2016;91:1022–8.
29. Dewey J. Experience and education. Touchstone, Simon and Schuster, New York, 1997. (Original work published 1938).
30. Greeno JG. On claims that answer the wrong questions. Educ Res 1997;26:5–17.
31. Greeno JG, Moore JL. Situativity and symbols: response to Vera and Simon. Cogn Sci 1993;17:49–59.
32. Norman DA. Cognition in the head and in the world: an introduction to the special issue on situated action. Cogn Sci 1993;17:1–6.
33. Clark A, Chalmers D. The extended mind. Analysis 1998;58:7–19.
34. Hutchins E. Cognition in the wild. Cambridge, MA: MIT Press, 1995.
35. Rogers Y, Ellis J. Distributed cognition: an alternative framework for analysing and explaining collaborative working. J Inf Technol 1994;9:119–28.
36. Cohen T, Blatter B, Almeida C, Shortliffe E, Patel V. A cognitive blueprint of collaboration in context: distributed cognition in the psychiatric emergency department. Artif Intell Med 2006;37:73–83.
37. Suchman LA. Plans and situated actions: the problem of human-machine communication. Cambridge University Press, 1987.
38. Katerndahl DA. Is your practice really that predictable? Nonlinearity principles in family medicine. J Fam Prac 2005;54:970–7.
39. Samuel A, Konopasky AW, Schuwirth LW, King SM, Durning SJ. Five principles for using theory: strategies for advancing health professions education research with clinician educators and new researchers. Acad Med 2019 (Accepted).