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Using Relational Reasoning Strategies to Help Improve Clinical Reasoning Practice

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Abstract

Clinical reasoning—the steps up to and including establishing a diagnosis and/or therapy—is a fundamentally important mental process for physicians. Unfortunately, mounting evidence suggests that errors in clinical reasoning lead to substantial problems for medical professionals and patients alike, including suboptimal care, malpractice claims, and rising health care costs. For this reason, cognitive strategies by which clinical reasoning may be improved—and that many expert clinicians are already utilizing—are highly relevant for all medical professionals, educators, and learners.

In this Perspective, the authors introduce one group of cognitive strategies—termed *relational reasoning strategies*—that have been empirically shown, through limited educational and psychological research, to improve the accuracy of learners' reasoning both within and outside of the medical disciplines. The authors contend that relational reasoning strategies may help clinicians to be metacognitive about their own clinical reasoning; such strategies may also be particularly well suited for explicitly organizing clinical reasoning instruction for learners. Since the particular curricular efforts that may improve the relational reasoning of medical students are not known at this point, the authors describe the nature of previous research on relational reasoning strategies to encourage the future design, implementation, and evaluation of instructional interventions for relational reasoning within the medical education literature. The authors also call for continued research on using relational reasoning strategies and their role in clinical practice and medical education, with the long-term goal of improving diagnostic accuracy.

Clinical reasoning is central to being a physician. It can be defined as the steps up to and including establishing a diagnosis and/or therapy and thus is a part of most activities in a physician's practice.[1] One result of suboptimal clinical reasoning is medical error. A recent review[1] notes that a wide variety of research studies suggest that breakdowns in the diagnostic process result in a staggering toll of harm and patient deaths. The authors of another recent review[2] of 25 years of U.S. malpractice claims note that "diagnostic errors appear to be the most common, most costly and most dangerous of medical mistakes." Thus, data are emerging that diagnostic errors are a pervasive problem in practice, contributing to the rising costs and suboptimal care outcomes seen in the United States.[3-5]

Research in clinical reasoning has explored the importance of a physician's fund and organization of knowledge as well as the breadth and flexibility in their reasoning strategies needed to succeed in clinical reasoning.[6] But how does a physician build organized knowledge as well as the needed depth and adaptability in reasoning strategies to optimize clinical reasoning and thus avoid errors? Although some previous work exists to address this question,[7,8] the clinical reasoning literature does not yet contain much explicit guidance in this regard. With that problem in mind, in this article we introduce one group of reasoning strategies—termed *relational reasoning strategies*—that have been empirically shown, through limited educational and psychological research, to improve the accuracy of learners' reasoning both within and outside of the medical disciplines.[9-13] We contend that relational reasoning strategies may help clinicians to be metacognitive about their own clinical reasoning, and that such strategies may be particularly well suited for explicitly organizing clinical reasoning instruction for learners.

There is a wealth of literature pointing to the importance of relational reasoning in general but very little specifically showing that such reasoning is important for medicine in particular. This is the state of affairs that we hope to remedy with this Perspective, which we hope will build interest about relational reasoning strategies among scholars of medical education.

Relational Reasoning Strategies

Relational reasoning refers to a body of strategies, discussed below, that support the fundamental ability of the human mind to identify meaningful patterns within any stream of information.[14-16] From this wide-reaching definition, it is not surprising that relational reasoning has been empirically demonstrated as critical to learning outcomes across the gamut of educational levels and academic disciplines, from elementary reading instruction[17] to middle-school mathematics,[18] high-school chemistry,[19] graduate-level engineering,[20] and learning in medical residencies.[10] Even beyond the educational context, relational reasoning has been identified as a requirement for the complex mental work of professional scientists, engineers, and physicians,[21-23] whose reasoning regularly involves complex patterns. Readers who are interested in a full accounting of past literature on relational reasoning should see published reviews focused on either the educational[14] or neuropsychological[15] antecedents of the construct.

The findings in this literature suggest that although nearly all learners (i.e., those at every level and within every discipline) are capable of some relational reasoning, there is significant variability in the reasoning performance across learners. This observed variability in relational reasoning strategic ability, coupled with observed gains on relational reasoning outcomes in response to explicit strategy instruction, leads to the general conclusion that relational reasoning strategies, although fundamental to human thinking, also appear to be malleable constructs that improve with education; this conclusion has been demonstrated with undergraduate students.[24] Although the particular curricular efforts that may improve the relational reasoning of medical students are not known at this point, one of our purposes in this article is to describe the nature of previous research on relational reasoning strategies, which we hope will lead to the design, implementation, and evaluation of instructional interventions for relational reasoning within the medical education literature.

Given recent empirical psychological findings,[25] relational reasoning may be enacted in at least four distinct strategies: *analogy, anomaly, antinomy,* and *antithesis*. These strategies differ based on the type of relation being mapped among ideas or pieces of information. The specific differences in the mapped relations among strategies, as well as prototypical examples, are presented in Table 1. Importantly, we do not contend that such exemplars of relational reasoning will be wholly new to either practicing physicians or medical learners. Indeed, evidence[11,22] suggests that adept problem-solvers in a number of disciplines, including medicine, are already engaged in relational reasoning strategies regularly in the course of their mental work. However, we do argue that the formal identification and study of the forms of relational reasoning may aid physicians in thinking fruitfully about their own reasoning (i.e., being metacognitive), or in explaining their thinking processes to learners who may not yet be so adept. Therefore, each of the forms of relational reasoning are introduced below with corresponding clinical examples.

Analogy

In certain reasoning scenarios, relations of similarity, termed *analogies*, can be mapped between and among sets of information.[26] For instance, when a resident identifies a correspondence between a patient whom the resident is examining and a textbook case the resident had previously reviewed, or when an attending clinical neurologist explains to residents that “some people have drawn an analogy between an aneurysm and a balloon…just stick a pin in the balloon,”[10] reasoning by analogy is clearly implicated. This balloon-to-aneurism analogy was taken from audio recordings of actual residents working with an attending clinical neurologist to make diagnoses and therapeutic decisions.[10]

Anomaly

When a discrepancy is perceived between a reasoned expectation and reality, an *anomaly* may be identified.[27] In the clinical reasoning context, anomalies can arise when the physical examination or a patient history reveals findings that do not match previously hypothesized conditions, or when laboratory tests result in findings that—based on previous examinations of a patient—were not expected. Notably, however, it may be common for even expert physicians to explain away anomalies without giving them the attention they require. This can happen when the physician relies only on pattern recognition, also known as system 1 thinking—which is rapid, often subconscious, and low-effort—especially if the anomaly may discredit a previously held expectation or theory.[28] This unfortunately common occurrence of not sufficiently attending to anomalies is related to the idea of confirmation bias, which has been more widely studied in the clinical reasoning literature.[29] Therefore, the ability and willingness to identify and resolve anomalies in data have been identified as critically important for success, both in clinical and scientific reasoning, and may represent a means to reduce diagnostic error. However, experimental tests of the actual improvement of diagnostic accuracy associated with training medical learners to reason with anomalies have not yet been carried out.

Antinomy

In situations of high diagnostic uncertainty, it may be unclear whether results are indeed anomalous or whether they indicate an as yet undetected patient condition. In these situations, relations of incompatibility, or *antinomies*, among multiple hypotheses or sets of symptoms may arise.[30] In this way, antinomies allow clinicians to use what they have observed, and their prior knowledge, to identify what something they are reasoning about is *not.* In clinical reasoning, antinomies are frequently implicated during the process known as *differential diagnosis*, in which individual patient symptoms are used to rule out possible diagnoses that the symptoms would be incompatible with.[22] For instance, when attending physicians instruct their learners to differentiate causes of cardiac and noncardiac chest pain, the physicians can be modeling reasoning by antinomy. Limited empirical work has shown that this strategy of relational reasoning may be less developed in medical students and residents than are the other relational reasoning strategies; those learners appear to rely more on attending physicians for identifying antinomies than for identifying any other strategy of relational reasoning.[10] Indeed, incorporating relational reasoning strategies explicitly into the existing discussion of the differential diagnosis could serve as a useful cognitive forcing strategy to reduce error and enhance learning.

Antithesis

Finally, whenever oppositional relations are identified among arguments or ideas, antitheses may arise.[31] In contrast to antinomies, which deal with incompatibility among ideas (e.g., a Venn diagram with nothing in the middle), antitheses focus on concepts that are related through a direct opposition or refutation. For example, one common cognitive task required of students in a variety of scientific disciplines, including medicine, is the reversion of an equation describing a chemical reaction. In this task, a chemical reaction must be understood from the “opposite direction” from which it was originally taught; this is an idea that can be less than intuitive for many students. Further, when clinical experts differ in their opinions—such as when one surgery team recommends the removal of a tumor while another declares the tumor inoperable—antithetical reasoning is required to resolve the disagreement. Although the existing limited empirical work[10] has found that antithetical reasoning—compared to analogical, anomalous, and antinomous reasoning—is comparatively rare among clinicians, that same evidence suggests that this strategy for reasoning is utilized when medical teams need to make important decisions for patient care, especially when members of the team disagree or when multiple options seem viable.

Comments on the four strategies

It is important to note that none of the relational reasoning strategies reviewed here can be effective without other critical precedents of clinical reasoning such as prior medical knowledge, sufficient motivation, and accurate patient data. Further, these strategies are meant to complement, not replace, other important clinical reasoning processes such as probability thresholds and risk assessment. For example, prior knowledge concerning the prevalence of a particular symptom in the population, or the risk of a specific patient having a particular condition, based on the patient's history, allows a clinician to determine whether a given symptom is anomalous or not. Although relational reasoning strategies can never replace the need for such Bayesian thinking, we believe they may be able to support it.

Relational Reasoning and Clinical Reasoning Theory

Relational reasoning strategies resonate with clinical reasoning theory as it currently exists. For example, dual process theory argues that physicians use two systems while engaged in clinical reasoning: (1) system 1 thinking, which is fast, low effort, and often subconscious, and (2) system 2 thinking, which is slower and requires conscious effort.[32,33] Within a dual process theory framework, it is understood that novices in any discipline must necessarily effortfully utilize system 2 as they acclimate to their discipline, while experts tend to rely more heavily on automated system 1 processing to make decisions.

In the same way, relational reasoning strategies, although they may be utilized effortfully and consciously by learners at first, may later become automated and subconscious. For example, with practice, expert clinicians may learn to automatically generate meaningful analogic cases, or notice anomalies in patient data, while learners may require the effortful scaffolding of these strategies. Of course, at times, experts utilize system 2 thinking when reasoning about a difficult case, or when patterns in data are not readily apparent when using their automated processes. Therefore, any of the relational reasoning strategies described here may occur either in an automatic–subconscious way or in an effortful–conscious way, depending on the specific clinician and case at hand.

To describe this phenomenon, some have proposed the more general term *relational thinking* to signify relational reasoning strategies that have become automated to support subconscious pattern recognition.[9] Also relevant to dual process theory, consciously applied relational reasoning strategies may be helpful in efficiently economizing clinicians' cognitive processing by forming relational patterns, relegating more tasks to system 1 thinking, and therefore freeing up the capacity for system 2 thinking. From this perspective, relational thinking or reasoning could potentially aid both system 1 and system 2 thinking.

Moreover, relational reasoning strategies may serve to help "toggle" individual clinicians' thinking from system 1 to system 2, therefore allowing a more analytical, as opposed to automatic, thought process at times. In this way, relational reasoning strategies may be considered *cognitive forcing strategies*,[34] which are specific metacognitive procedures designed to reduce medical errors, first identified in the emergency room setting but useful in all areas. For example, during a *diagnostic time out*,[35] clinicians take time to metacognitively ask themselves, "What am I missing?" and "What else might this condition be?" Such a diagnostic time out is an instance in which relational reasoning strategies may come into play. However, in contrast to such explicitly metacognitive strategies, relational reasoning may also operate at the general cognitive level (i.e., not a solely metacognitive level), making relational reasoning strategies equivalent to cognitive forcing strategies sometimes but not always.

Although we do contend that the flexible use of all four relational reasoning strategies described here would likely lead to a reduction in diagnostic error, we also realize that the sole use of any one strategy could actually reinforce common clinical reasoning mistakes such as representativeness error. For example, a clinician who solely drew analogies among cases might miss critical discrepancies or incompatibilities among them. Given this potentially important interface between relational reasoning and cognitive forcing strategies, we believe further investigation of their overlap is warranted and necessary.

Likewise, Ausenbel's Assimilation Learning Theory[36] distinguishes *meaningful learning* from *rote memorization* by stressing the importance of building a network of interconnected conceptual relationships. This theory has led to the development of concept mapping procedures, which are growing in popularity in health professions education and other educational fields.[37] In the clinical education context, concept mapping may be utilized to support students as they endeavor to simultaneously retain large amounts of information and hierarchically organize that information so that it can be efficiently used during future instances of clinical reasoning or other forms of complex problem solving.[38] Moreover, in concept mapping, conceptual relations take the form of linking words and crosslinks, and these may be conceptualized as taking the form of relational reasoning strategies such as "similar to" (analogy), "discrepant from" (anomaly), "incompatible with" (antinomy), or "opposed to" (antithesis). Although the intersections among concept mapping crosslinks and relational reasoning strategies have not yet been empirically explored, we contend that such a line of inquiry may be particularly fruitful in the future.

Relational Reasoning as Strategies for Clinical Reasoning

In authentic problem-solving scenarios, relational reasoning strategies should not be utilized independently but, instead, should operate in concert with one another, to maximize the probability of a solution being obtained; thus flexibility in the use of these strategies is needed. For example, on an inpatient ward team, the clinical reasoning process often begins with the identification of anomalous aspects of a given patient case (e.g., "With no family history of coronary artery disease and his young age, it's unusual that he has suffered from an acute myocardial infarction"). In empirical work, such anomalies tended to be noticed in clusters, with the identification of an initial anomaly significantly increasing the probability that others will immediately be verbalized.[10] At this point in the research literature, the cause of this pattern is not well understood, but it may arise because of cognitive priming effects, in which an initial anomaly makes it more likely that another will be noticed. Alternatively, it may be the result of social or cultural influences on when and whether it is acceptable to voice an anomaly to a group. In our view, this finding warrants future investigation, especially because the explicit attention to anomalies, and associated questioning of previous diagnoses, could reduce the risk of premature closure of the process of differential diagnosis.[39]

To converge on a diagnosis, clinicians also often map similarities and differences among their current and previous patients or prototypical exemplars, which is consistent with script theory.[40] Such a process necessarily includes instances of analogical thinking (e.g., "I'm relating her to our previous patient, about whom we entertained the same three diagnoses") and antinomous reasoning (e.g., "This is non-cardiac chest pain"). Of course, if further anomalies are identified that do not match an initial diagnosis, the process may be repeated until a refined diagnosis, which all members of the team concur with, can be formulated. Note that the order of relational reasoning strategies offered above as part of the diagnostic process is merely an exemplar; the particular relational reasoning strategies employed in any real-life scenario, and their order, will necessarily differ depending on the specific case and clinician(s).

After a diagnosis is made, therapeutic decisions may begin with the mapping of possible treatments from previous patient cases onto the current case, a process that may require analogical reasoning (e.g., “Our last elderly patient with postoperative delirium responded to the following regimen; perhaps we should consider a similar approach?”). Also, the clinical team must identify whether or not previously used treatment options were appropriate for the particular patient at hand. For example, antinomous reasoning can be useful to a clinical team when identifying contraindications (e.g., considering anticoagulant therapy for a patient with a high risk of falls). The end of the clinical reasoning process may be marked with an instance of antithetical reasoning—as a way to open the discussion up to oppositional or competing points of view—before making a final decision about treatment. For example, an attending physician may invite residents to consider alternate points of view by asking, “Would anybody like to take the opposite stance?” It should be also noted that, at any point during the therapeutic decision-making process, the presence of anomalies could signal that clinicians should rethink either their therapeutic recommendation or their original diagnosis.

Based on these findings and others in the relational reasoning literature,[10,15,21] we are convinced that analogies, anomalies, antinomies, and antitheses appear to be effective problem-solving strategies that may be jointly utilized when complex clinical problems must be solved.

Relational Reasoning as an Instructional Strategy

Although instructional curricula for the improvement of diagnostic accuracy and the prevention of clinical reasoning errors have been posited in the past,[40,41] we contend that the use of relational reasoning strategies may help build on those past efforts. Relational reasoning has been shown to be highly effective as an instructional strategy for teachers to employ with their students.[42] For instance, it has been known for decades that analogies are effective at explaining complex scientific phenomena to learners across multiple academic levels (e.g., elementary, secondary, and undergraduate).[43] However, more recently, evidence suggests that organizing instruction around anomalies, antinomies, and antitheses may also be helpful. For example, responding to unexpected findings (anomalies) in experimental data,[44] the explanation of incompatibilities (antinomies) among taxonomic or ontological categories,[45] and the presentation of oppositional (antithetical) points of view[46] have all been shown to improve scientific understanding in students. Because of the demonstrated success of relational reasoning instructional techniques in various fields, we believe these instructional benefits may also translate to the education of medical professionals; future investigations could explore the explicit incorporation of these strategies into learners' clinical reasoning performance across the educational continuum in the health professions. Also, since many existing studies of relational reasoning strategies within the educational and psychological literatures specifically measure only one strategy,[14] it could be hypothesized that their combined effect may be even greater than the current literature suggests.

In addition, limited available evidence from clinical neurologists[10] suggests that when attending physicians are reasoning alongside residents, the attending physicians appear to verbalize analogies and antinomies as a way to guide residents' thinking toward diagnostic and treatment solutions. For example, attending physicians may especially use antinomies to signal to residents that they are on the wrong track, saying things like, "You have to look at [different cases]…it's not a pneumonia, so what is the best way to address this?"[10] Indeed, limited evidence suggests that during the clinical reasoning process, attending physicians may be twice as likely as residents to verbalize analogies, antinomies, and antitheses,[10] which implies that they may be used as instructional strategies.

In contrast, attending physicians have been shown to be only half as likely as residents to point out anomalies in patient cases, implying this relational reasoning strategy may have been effectively developed in learners by the time their residencies began,[10] In general, as indicated above, available evidence suggests that some medical education contexts, including clinical residencies, may benefit from the incorporation of relational reasoning instructional strategies to guide learners on the most advantageous path through complex clinical reasoning scenarios. However, the specific knowledge and skills of the clinician(s) and the particular aspects of the case will always be needed to be taken into account to determine the probability of diagnostic error. In many ways, relational reasoning strategies are like tools, which can be more or less effective depending on the individual wielding them. Available evidence[23,44] does suggest that relational reasoning strategies may improve problem-solving on average, but they can never guarantee a correct solution to the problem.

Future Directions

Given the theoretical perspective and findings from the literature described here, a number of relevant future directions may be identified within both clinical reasoning research and education. Possible relevant future research projects associated with relational reasoning's role within clinical work include, but are certainly not limited to, identifying the existing relational reasoning requirements of high-stakes medical assessments such as board certifications; examining the differential role of relational reasoning within disciplines or specialties of clinical practice (e.g., surgery or cardiology); longitudinally examining the development of relational reasoning strategies as medical students become practicing physicians to enable theory-building in clinical reasoning; and empirically testing whether explicit use of relational reasoning strategies can improve clinical reasoning performance of learners in all areas and levels of health professions education. Importantly, the enactment of successful relational reasoning strategies appears to differ between disciplines (e.g., engineering and chemistry[22]), and therefore it is unlikely that any one "recipe" for reasoning success exists for all clinicians and clinical contexts. However, with continued research, it may be possible to find commonalities in reasoning requirements across clinical contexts, and therefore make generalizable recommendations to learners. Indeed, existing psychometric measures of relational reasoning[47] may be utilized in this ongoing research endeavor. Many such measures have shown strong reliability and internal validity evidence, require relatively short time periods to complete, and have been shown to predict relevant academic outcomes across a variety of disciplines.[14]

Also, since relational reasoning strategies are potentially foundational to clinical reasoning, this opens the door for the explicit inclusion of those strategies in medical education, as well as for the refinement of curricula designed to support learners' clinical reasoning ability. Although the empirical testing of instructional interventions that include relational reasoning strategies within medical education remains in the future, given the existing literature, we hypothesize that explicit instruction (either individually or in a group setting) on relational reasoning strategies may help novice clinicians organize their knowledge more effectively, increase the accuracy of their clinical reasoning, and reduce their likelihood of diagnostic error. At this point, such a statement is only a hypothesis, but it is a hypothesis that we believe should be specifically addressed in the future through a wide variety of educational research methodologies, especially the design, implementation, and evaluation (ideally with a randomized-control trial research design and reliably measured clinical reasoning outcome) of instructional interventions for medical students that explicitly incorporate relational reasoning strategies.

The strategies for relational reasoning we have discussed here may be a fruitful paradigm for ascertaining how clinicians converge on optimal solutions and avoid medical errors, given the information presented to them and their previous knowledge. Given this hypothesis and future research inquiries, as well as the potentially devastating consequences of medical error, we contend that continued attention to relational reasoning strategies in clinical reasoning research is warranted, and that such research may potentially improve the medical profession's ability to meet its ultimate clinical reasoning goal: accurate diagnoses and optimal treatment for patients.

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Table 1

Relational Reasoning Strategies With Hypothetical Examples From Clinical Situations[a]

Strategy	Core relation	Clinical example
Analogy	Similarity	An abdominal aortic aneurism is similar to a tire that has developed a weak area, stretches, thins, and eventually bursts.
Anomaly	Discrepancy/ Unusualness	With no history of arthritis, it is unusual that the patient has inflammation of multiple joints.
Antinomy	Incompatibility	In an adult patient who presents with headache and photophobia, but has no fever and has normal mental status and a normal physical exam, the diagnosis of bacterial meningitis is very unlikely.
Antithesis	Opposition	Physicians examine a patient's CT scan. The surgeons think they should perform coronary artery bypass grafting, while the cardiologists say the opposite: that the patient's coronary artery disease should be medically managed.

[a]Relational reasoning strategies may help clinicians to be metacognitive about their own clinical reasoning; such strategies may also be particularly well suited for explicitly organizing clinical reasoning instruction for learners.