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## Review

# Comprehensive process model of clinical information interaction in primary care: results of a “best-fit” framework synthesis

Tiffany C Veinot,<sup>1</sup> Charles R Senteio,<sup>2</sup> David Hanauer,<sup>3</sup> and Julie C Lowery<sup>4</sup>

<sup>1</sup>School of Information and School of Public Health, University of Michigan, Ann Arbor, MI, USA, <sup>2</sup>Department of Library and Information Science, School of Communication and Information, Rutgers University, New Brunswick, NJ, USA, <sup>3</sup>Department of Pediatrics, Medical School, University of Michigan, Ann Arbor, MI, USA and <sup>4</sup>Center for Clinical Management, Research, VA Ann Arbor Healthcare System, University of Michigan, Ann Arbor, MI, USA

Corresponding Author: Tiffany Veinot, School of Information, University of Michigan, 3443 North Quad, 105 S. State Street, Ann Arbor, MI 48109-1285, USA. E-mail: tveinot@umich.edu, Phone/Fax: 734-615-8281.

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## ABSTRACT

**Objective:** To describe a new, comprehensive process model of clinical information interaction in primary care (Clinical Information Interaction Model, or CIIM) based on a systematic synthesis of published research.

**Materials and Methods:** We used the “best fit” framework synthesis approach. Searches were performed in PubMed, Embase, the Cumulative Index to Nursing and Allied Health Literature (CINAHL), PsycINFO, Library and Information Science Abstracts, Library, Information Science and Technology Abstracts, and Engineering Village. Two authors reviewed articles according to inclusion and exclusion criteria. Data abstraction and content analysis of 443 published papers were used to create a model in which every element was supported by empirical research.

**Results:** The CIIM documents how primary care clinicians interact with information as they make point-of-care clinical decisions. The model highlights 3 major process components: (1) context, (2) activity (usual and contingent), and (3) influence. Usual activities include information processing, source-user interaction, information evaluation, selection of information, information use, clinical reasoning, and clinical decisions. Clinician characteristics, patient behaviors, and other professionals influence the process.

**Discussion:** The CIIM depicts the complete process of information interaction, enabling a grasp of relationships previously difficult to discern. The CIIM suggests potentially helpful functionality for clinical decision support systems (CDSSs) to support primary care, including a greater focus on information processing and use. The CIIM also documents the role of influence in clinical information interaction; influencers may affect the success of CDSS implementations.

**Conclusion:** The CIIM offers a new framework for achieving CDSS workflow integration and new directions for CDSS design that can support the work of diverse primary care clinicians.

**Key words:** theoretical model, primary care informatics, information-seeking behavior, information use, clinical decision support

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## BACKGROUND AND SIGNIFICANCE

Clinical decision support systems (CDSSs), whether stand-alone or embedded in an electronic health record (EHR), represent “the use of information and communication technologies to bring relevant

knowledge to bear on the health care and well-being of a patient.”<sup>1</sup>

In the United States, CDSSs have been part of meaningful use incentives due to their potential to improve health care quality.<sup>2</sup> However, despite having a positive impact on various clinical

processes,<sup>3–6</sup> they have not yielded consistent improvements in primary care settings,<sup>7–12</sup> which are characterized by continuous, comprehensive, coordinated care that serves as the first health care contact for patients.<sup>13</sup>

Multiple factors underlie the failure to realize the potential of CDSSs in primary care. There is a gap in designing CDSSs to comprehensively address problems clinicians face<sup>14</sup> and to integrate well into their workflow, and this is perhaps more acute in primary care settings, since CDSS implementations may be too inflexible to accommodate the variability and time constraints of these settings.<sup>15,16</sup> Indeed, 2 chief elements of primary care CDSSs, alerts and reminders, are often ignored due to situational inappropriateness and workflow disruption.<sup>17,18</sup> Needed functionality may also be missing: EHRs in ambulatory care settings have fewer front-end CDSS capabilities than those in inpatient settings.<sup>19</sup> Furthermore, most research has focused on inpatient settings<sup>20–23</sup> rather than primary care.<sup>24</sup>

Additionally, CDSSs for primary care have been chiefly designed to support the decision-making of primary care physicians (PCPs).<sup>4,7,11,25,26</sup> Comparatively few focus on the needs of other providers, such as nurse practitioners (NPs) and physician assistants (PAs),<sup>27,28</sup> who represent almost a third of US primary care clinicians.<sup>29</sup> These practitioners often have significant decision-making authority: NPs can prescribe medication without physician oversight in 17 US states.<sup>30,31</sup> They also make different types of decisions: NPs focus more on health promotion and education, counseling, and preventive care than PCPs. Accordingly, their information interaction patterns may differ.<sup>32,33</sup> Thus it is important to develop CDSSs that support these practitioners.

## Objectives

Robust CDSS functionality effectively integrated into primary care is needed to support diverse practitioners. This requires a stronger conceptual foundation,<sup>34</sup> particularly regarding how providers interact with information.<sup>35</sup> However, no theoretical framework addresses the complete process of primary care information interaction. Therefore, we developed a model guided by 2 research questions: (1) How do primary care clinicians interact with information as they make decisions at the point of care? and (2) What factors influence primary care clinicians' point-of-care information interactions?

## METHODS

We used the “best fit” framework synthesis method, increasingly used in health services research,<sup>36,37</sup> to construct a model based on published empirical findings.<sup>38–40</sup> This involves systematic searching and iteratively constructing a theoretical framework based on the literature (see Figure 1).

### Search strategy and inclusion criteria

We performed searches in PubMed, Embase, the Cumulative Index to Nursing and Allied Health Literature (CINAHL), PsycINFO, Library, Information Science, and Technology Abstracts, Library and Information Science Abstracts, Library Literature, and Engineering Village. Searches included articles published between 1980 (when personal computers became widely available) and June 2015. Theoretical literature searches used strategies contained in the Behavior of Interest, Health context, Exclusions, and Models or Theories (BeHEMoTh) framework,<sup>38</sup> while empirical-only searches used the companion strategy, Sample, Phenomenon of Interest, Design, Evaluation, and Research (SPIDER).<sup>38</sup> Both incorporated terms concern-

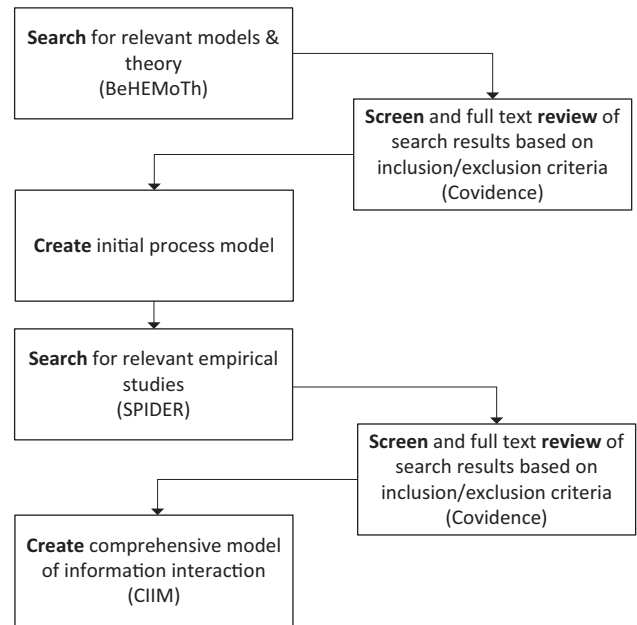


Figure 1. Flowchart of overall approach.

ing information interaction and primary care providers (eg, PCPs, NPs, and PAs) or primary care settings (see Supplementary Appendix 1). For our purposes, primary care was defined as care that is the first health care contact and is continuous, comprehensive, and coordinated<sup>13</sup>; despite differences in practice from country to country, we included care labeled as “primary care” from any country if it conformed to this broad definition. Two authors (CS, TV) independently screened the titles and abstracts of retrieved articles for concordance with inclusion and exclusion criteria (see Supplementary Appendix 2) using Covidence software.<sup>41</sup> Any areas of disagreement were identified via Covidence and discussed, and agreement regarding inclusion or exclusion was reached.

### Data abstraction and content analysis

The two authors developed a set of concepts<sup>42</sup> through content analysis, reviewing each BeHEMoTh article to extract concepts representing documented parts of the clinical information interaction process and factors influencing it. The 2 authors each reviewed the full set of BeHEMoTh articles independently and then discussed the resulting codes, including any areas of disagreement. If they did not already exist, the 2 authors gave these concepts new labels and compared and contrasted them to identify potential areas of overlap; this facilitated the combination and/or deletion of categories to create discrete, non-overlapping model elements. The 2 authors then developed a codebook based on these concepts (see Supplementary Appendix 3); the final codebook reflects consensus between them.

Using EndNote<sup>TM</sup> citation management software, the 2 authors then deductively assigned codes to each BeHEMoTh article based on whether it showed that the concept was part of or influenced the process; each author completed approximately half of the coding. Using a cross-case, time-ordered display,<sup>43</sup> the 2 authors plotted the process described by concepts and relationships contained in each article, iteratively identifying their place in the overall information interaction. These analyses produced an initial model based on published models and theory, including empirical studies that developed

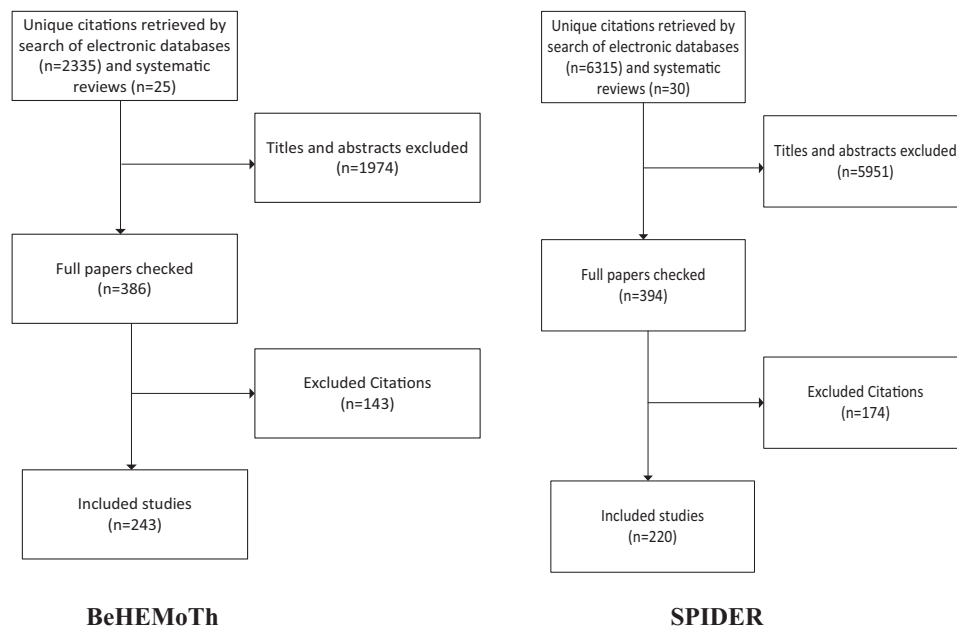


Figure 2. Flowcharts of BeHEMoTh and SPIDER searches for literature

theories/models, such as qualitative grounded theory studies and regression models.

The 2 authors updated the model based on SPIDER searches for empirical literature that did not use explicit theories or models. They then deductively assigned codes to each article based on whether it showed that the concept influenced or was part of the process; this collaborative process involved independent coding of the complete set of articles with regular checkpoints to discuss and resolve any disagreements concerning the codes and their application. Simultaneously, the 2 authors constantly compared<sup>44</sup> the literature to the codes and initial model to refine them and identify new concepts. They systematically documented the empirical support for every concept (see Supplementary Appendix 4) and edited the cross-case, time-ordered display<sup>43</sup> as articles were incorporated. All model components are based on at least one empirical study (Figure 4). They also documented whether each major component was supported by empirical research in relation to PCPs, NPs, and PAs to develop a model applicable to each clinician type (see Supplementary Appendix 5). We considered creating separate models for each type, but found this unnecessary; all components were supported by research conducted with both PCPs and NPs. Though there was less research on PAs, no available findings conflicted with the model in Figure 4 (Supplementary Appendix 5).

## RESULTS

### Search results

The BeHEMoTh search generated 2335 unique citations (see Figure 2). Additionally, citations from 5 systematic reviews identified in the searches were reviewed<sup>45–49</sup> for additional citations ( $n=25$ ). A total of 386 papers were retrieved. As Figure 2 shows, 243 satisfied the inclusion criteria. The empirical articles in this set primarily originated from the United States (68, 28%), Britain (34, 14%), Australia and New Zealand (12, 5%), and Canada (10, 4%).

The SPIDER search generated 6315 unique citations (see Figure 3). Additionally, citations from 5 systematic reviews were reviewed<sup>45–49</sup> to

identify non-theoretical citations ( $n=30$ ). A total of 394 papers were retrieved. As Figure 2 shows, 220 satisfied the inclusion criteria. These articles primarily originated from the United States (113, 51%), Britain (37, 17%), Canada (17, 8%), the Netherlands (11, 5%), Scandinavian countries (8, 4%), and Australia and New Zealand (5, 2%).

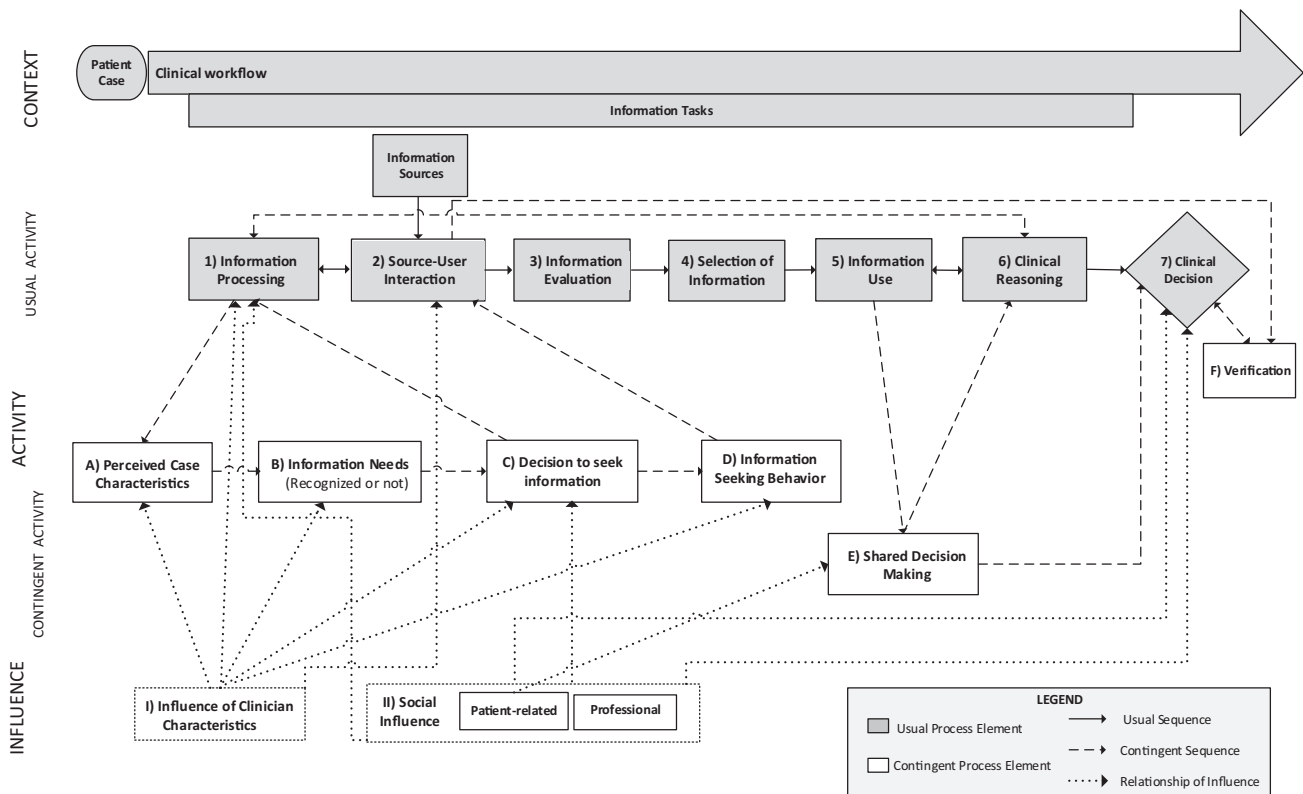
### Comprehensive model of clinical information interaction in primary care

The comprehensive model of clinical information interaction in primary care, abbreviated as the Clinical Information Interaction Model (CIIM), has 3 main parts: (1) context, (2) activity (usual and contingent), and (3) influences (see Figure 3 for an overview and Figure 4 for a detailed view). For parts 1 and 2, shaded boxes are usual parts of the context and process; white boxes represent contingent components (ie, ones that take place under only certain circumstances). Solid lines with arrows represent activity sequences; dashed lines represent contingent processes. Boxes are numbered sequentially to facilitate explanation. For part 3, dotted lines represent relationships of influence on activities, and line numbers link relationships to sources of influence. The descriptions below refer to details contained in Figure 4.

#### Part 1: Context

*Patient case.* The model begins with the patient case, since the key task of primary care is “contributing to the solution of patients’ problems.”<sup>50,51</sup>

*Clinical workflow.* Information interaction is part of the clinical workflow, beginning with the patient case. Clinical workflow, typically organized around the patient visit, refers to “the flow of care-related tasks . . . in the management of a patient trajectory.”<sup>52</sup> Steps include preappointment tests,<sup>53</sup> patient intake,<sup>53,54</sup> patient examinations by providers,<sup>53,55</sup> consultations with allied health professionals,<sup>53,56</sup> clinical decisions such as follow-up appointments,<sup>53,57</sup> and orders for medications or consultations.<sup>53,54</sup> Failing to optimally integrate people, information, and technology<sup>54</sup> may lead to



**Figure 3.** Overview of the Comprehensive Process Model of Clinical Information Interaction in Primary Care (CIIM)

workarounds, ways of working that address perceived system limitations.<sup>58–62</sup> Workarounds can become de facto elements of the workflow.

**Information tasks.** Information tasks, subparts of the workflow,<sup>63</sup> include reviewing documentation, taking histories, examining patients, documenting patient data, placing orders, and printing documents. They may be interspersed with other tasks during patient visits.<sup>64</sup> As part of the overall context, information tasks determine the information sources used and the information processing activities that take place.

**Information sources.** Information tasks rely upon available sources, including documents, people, and systems that provide information.<sup>65</sup> Clinicians most frequently access information directly from patients, particularly during examinations and while taking histories. Patients are often the sole source of pertinent information such as psychosocial histories.<sup>66–68</sup> The patient box is shaded, since this is a usual source of information.

In primary care settings that have adopted EHRs, the EHR is an information source of great importance, and EHRs are among the most frequently used sources. Clinicians use EHRs to review and record information about patients, including problem lists, current therapies, test results, and patient assessments.<sup>69</sup> The EHR box is also shaded, since this is a usual source of information.

As needed, professional colleagues are consulted about general medical knowledge and care of specific patients.<sup>32,49,50,70–77</sup> This box is unshaded, as they are typically consulted in response to a specific need or circumstance.

In some cases, clinicians access quick-reference sources such as drug handbooks.<sup>32,49,50,74,76,78</sup> These sources, often integrated into

EHRs, are arranged to support fast information retrieval; this may favor their use in time-pressured settings.<sup>79–81</sup> This box is unshaded for the same reasons as above.

Evidence summaries synthesize multiple studies, using transparent methods to arrive at relevant conclusions. These include published sources such as DynaMed as well as clinical practice guidelines.<sup>82</sup> They are used less often than each of the aforementioned sources, and typically as needed, and thus this box is unshaded.

### Part 2. Activity: Usual activity

Usual activities are those that are described in the literature as happening in most situations; these are not contingent upon special circumstances to occur. These activities are part of a process or series of actions taken toward a given purpose.

**Information processing (Box 1).** Information processing is a cognitive activity involving computations or operations on mental representations.<sup>83,84</sup> Processing involves perceiving information in the environment and integrating it with human memory.<sup>84</sup> It draws upon perception, attention, and memory<sup>85</sup> and is facilitated by cognitive structures called “schemata,” which are used as “slots” where new information is “inserted.”<sup>85</sup> Schemata concern people, events, and roles<sup>86</sup> and result from clinical knowledge (Box 1). Schemata allow filtering of irrelevant information about patients. Therefore, schemata undergird the processes of perceiving and focusing on information. “Scripts,” a hallmark of expertise,<sup>55</sup> are a type of schema “that [represent] generalized events as a unit.”<sup>87</sup> “Illness scripts” facilitate recognition of illness in diagnostic decision-making.<sup>88</sup>

**Source-user interaction (Box 2).** Source-user interactions are products of information sources and user behavior, potentially including

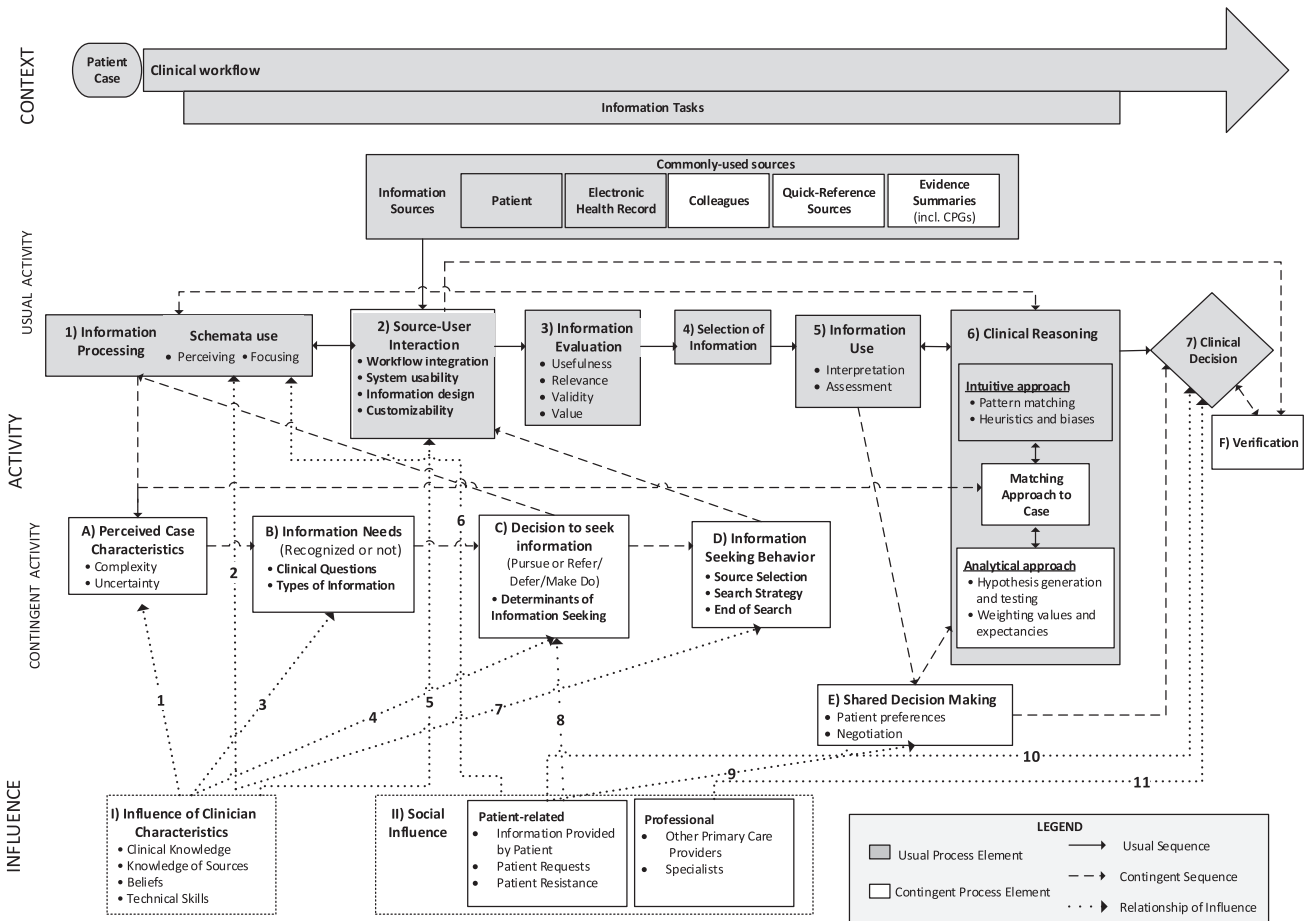


Figure 4. Comprehensive Process Model of Clinical Information Interaction in Primary Care (CIIM)

information-seeking behavior (Box D). Source-user interactions feed into information-seeking processing (Box 1), and vice versa.

Workflow integration, or the fit between users' activities and system design, affects primary care clinicians.<sup>89</sup> It has been defined in a clinical context as the "[a]ppropriate sequence of screens, context, type and timing ... by clinical task."<sup>90</sup> A key aspect relates to time spent completing tasks when using a technology.<sup>73,78,91-94</sup> Task interruption is another vital aspect; CDSSs that "push" information to clinicians and require a response are more interruptive.<sup>90</sup>

System usability is a system's capacity "to allow users to carry out their tasks safely, effectively, efficiently, and enjoyably."<sup>95</sup> EHR and CDSS usability is a significant focus of existing research<sup>96,97</sup> that has prompted efforts to develop design principles for clinical informatics<sup>90</sup>; new CDSSs increasingly incorporate user-centered design methods and usability evaluations into their development (eg, <sup>98-101</sup>).

Information design concerns "defining, planning and shaping ... the contents of a message ... with the intention of achieving particular objectives."<sup>102</sup> Clinicians desire comprehensible and visible content, synthesis of multiple pieces of information, recommendations and other content oriented toward action, provision of rationales, prioritization of messages, and personalization for particular patients.<sup>94,100,103-111</sup>

Customizability – the ability to modify technology according to user requirements – allows for smoother integration into an environment. For example, clinicians appreciate the ability to modify drug alert thresholds.<sup>105,112</sup>

*Information evaluation (Box 3).* Information processed through source-user interaction is typically evaluated: judgments are made about its worth according to specific criteria. Clinicians evaluate information according to its usefulness, or whether it can be readily acted upon,<sup>75,113-118</sup> its relevance to specific patients and situations,<sup>119,120</sup> its validity (accuracy and correctness),<sup>75,113,114,121-123</sup> and its value, or importance<sup>124</sup> due to novelty<sup>117</sup> or impact.<sup>120,125</sup> Evaluating information is associated with its selection for use.<sup>113,121,122,126-128</sup>

*Selection of information (Box 4).* Selection refers to choosing the most suitable information for a specific purpose.<sup>65</sup> This can occur without prompting, as when clinicians weigh information while taking histories and examining patients,<sup>129,130</sup> or in response to a CDSS such as an alert or reminder; clinicians accept the information provided<sup>131</sup> or reject it by ignoring or overriding reminders or alerts.<sup>110,117,128,132-134</sup> Information can also go unnoticed, and therefore be unselected.

*Information use (Box 5).* Selected information is then used. Information use is physical and mental action undertaken as new information is connected to a person's current knowledge base.<sup>135</sup> Interpretation is part of information use and involves assigning meaning by placing information in the context of a patient case.<sup>85,136</sup> Clinicians may struggle with interpretation<sup>137</sup> due to difficulties with comprehension<sup>138-141</sup> or ambiguity.<sup>142</sup> Clinical reasoning follows from interpretation.<sup>136</sup>

Assessment involves using information to evaluate or estimate the nature or quality of a clinical issue. Assessments might be thought of as “intermediate constructs” generated to “partition problems” and draw conclusions.<sup>85</sup> Assessment types include (1) the patient’s emotional and physical state,<sup>143,144</sup> (2) the probability of disease,<sup>88,145,146</sup> (3) the severity of the condition,<sup>145,147–149</sup> (4) the urgency of the problem,<sup>138</sup> (5) the potential benefit or efficacy of treatment or action, such as hospital admission,<sup>150–152</sup> (6) the feasibility of options,<sup>153,154</sup> and (7) equipoise, or whether more than one legitimate choice exists.<sup>57</sup> Clinicians also assess risk in relation to negative outcomes, such as falling or disease progression.<sup>83,141,150,155–165</sup>

*Clinical reasoning (Box 6).* Clinical reasoning is a “context-dependent way of thinking and decision making in professional practice to guide practice actions. It involves the construction of narratives to make sense of the multiple factors and interests.”<sup>166</sup> Reasoning has 2 main types, intuitive and analytical.

*Intuitive approach.* The intuitive approach is effective in routine situations<sup>167</sup> and often used by clinicians with significant expertise.<sup>168,169</sup> It is “fast reflexive, and requiring minimal cognitive resources,”<sup>170</sup> bypassing conscious thought.<sup>171</sup> Intuitive processes are largely based on pattern recognition,<sup>170</sup> “collating and categorizing many information cues”<sup>167</sup> and matching them with mental pictures<sup>172</sup> or schemas.<sup>168</sup> Pattern recognition follows inductive logic.<sup>173,174</sup> Intuitive reasoning also uses heuristics, or “strategies . . . to simplify judgmental tasks.”<sup>175</sup> Dozens of heuristics are commonly used in primary care.<sup>175–177</sup>

*Analytical approach.* Analytical reasoning involves both using and generating assessments; hence, the line linking Boxes 5 and 6 is bidirectional. The analytical approach is “slow, deliberate, and demanding [of] . . . conscious effort.”<sup>170</sup> In the context of diagnostic decisions, it begins with hypothesis generation.<sup>137,168,171,174,178</sup> Systematic hypothesis testing might follow<sup>168,171</sup> by asking the patient questions, looking for signs in the physical examination, or ordering tests.<sup>174</sup> Treatment decisions involve weighing values and expectancies: (1) choosing decision criteria and assigning their relative importance, and (2) estimating outcomes for them.<sup>152,168</sup>

*Matching approaches to cases.* Clinicians can move between intuition and analysis, or adopt both. They match their reasoning approach to the patient case based on its cognitive demands.<sup>85,143,167,174,179</sup> For diagnostic decisions, complexity and uncertainty determine recognition speed; quickly recognized cases are more likely to be handled intuitively.<sup>85,173,179</sup>

*Clinical decision (Box 7).* Clinical decisions follow clinical reasoning. In primary care, decisions may be made or deferred during a patient visit.<sup>180</sup> Decisions may occur on a onetime basis or be part of an ongoing process, revisited and potentially revised.<sup>181,182</sup>

#### Contingent activity

Contingent activities are those that, according to the literature, take place only under specific circumstances.

*Perceived case characteristics (Box A).* Through information processing, clinicians may perceive specific case characteristics, attributes

of patients and/or situations that determine how cases are handled; these characteristics are not always present. Case complexity concerns situations that are difficult to understand or address. Uncertainty refers to doubt, ambiguity, or indeterminacy; it may emerge from the probability of future events, the strength of the scientific evidence, missing or unusable information, or gaps in knowledge.<sup>183–185</sup> Primary clinicians experience more uncertainty than specialists.<sup>170,186</sup> While clinicians may not always recognize knowledge gaps,<sup>94,187</sup> recognized gaps result in cognitive uncertainty,<sup>185</sup> generating perceived information needs.<sup>94,188,189</sup>

*Information needs (Box B).* Information needs refers to “a gap in knowledge or a deficit in understanding.”<sup>56</sup> The perception of information needs is contingent upon the recognition of case complexity and/or uncertainty. Primary care information needs are commonly expressed as clinical questions, or questions asked by clinicians in the course of caring for patients.<sup>72,190–193</sup> PCPs have 0.18<sup>93</sup> to 1.58 questions that can be answered by medical literature per patient encounter<sup>190</sup>; NPs have 0.57 such questions per encounter.<sup>32</sup> Clinical questions have been classified by topic (eg, organ system), function (eg, treatment, drug dosage),<sup>32,74,194,195</sup> and diagnosis (eg, causes of symptoms).<sup>32,74,195,196</sup>

Information needs have been classified by the type of information needed.<sup>193</sup> Clinicians indicate a need for general medical knowledge-based information,<sup>77,156,191,193,197</sup> including “causal models and general procedures accepted throughout” a discipline,<sup>198</sup> often found in academic sources such as journals. Another form, epidemiological information, includes aggregate population data,<sup>199</sup> such as recent patterns of illness or local antibiotic resistance.<sup>200</sup>

Another need is for logistic information or local knowledge about getting things done.<sup>77</sup> Also needed is patient-specific information, both formal and codified (as in EHRs or databases) and informal and uncoded (such as information from patients).<sup>198</sup>

*Decision to seek information (Box C).* The decision to seek information first requires recognizing an information need. However, answers are not pursued for 15%–78% of questions generated during primary care encounters.<sup>45</sup> In making decisions to not seek information, clinicians may employ strategies of deferral, referral or “making do,”<sup>48</sup> returning them to the general process of information processing. Specific determinants of information-seeking increase or decrease the likelihood of information-seeking (Box D). Situational determinants that reduce the likelihood include time pressure<sup>1,72,73,78,93,109,201</sup> and lower perceived urgency and/or importance.<sup>32,78,93,104,195,201,202</sup>

*Information-seeking behavior (Box D).* Information-seeking behavior is contingent upon a decision to seek information. Source selection is an early step<sup>79</sup> that can recur when using more than one source.<sup>203</sup> Clinicians use selection criteria to choose sources.<sup>204</sup> They choose sources due to the perception of fit between question and source,<sup>94,203</sup> and source characteristics. Pertinent characteristics include perceived benefits such as credibility,<sup>71,123,205–208</sup> comprehensiveness,<sup>94,205</sup> and currency<sup>75,94,109,205</sup>; perceived access costs such as convenience<sup>50,71,75,94,123,208–210</sup> and applicability<sup>50,94,123,205,206</sup>; and perceived efficiency of use.<sup>94,203,205,207,208,210</sup> The number of sources selected increases with the complexity of the question,<sup>76,207</sup> while the specific order of selection may be habitual or deliberate.<sup>94,203</sup>

Clinicians may use simple search strategies and tactics such as limits or controlled vocabulary terms<sup>94,211</sup> at the point of care, and

end the search due to perceived answer sufficiency<sup>94,207</sup> or frustration leading to search abandonment.<sup>93,94</sup> Each strategy and tactic is implemented through interaction with sources.

*Shared decision making (Box E).* Shared decision making (SDM) is advocated for screening, treatment, or management decisions that clinicians assess to be characterized by equipoise; it is therefore triggered by this special clinical circumstance.<sup>57</sup> In SDM, patients are given information about options<sup>212</sup> and encouraged to clarify their preferences.<sup>154,184,212–215</sup> Contributing to analytical reasoning, patients are encouraged to consider “likely benefits and harms of each so that they can . . . help select the best course of action.”<sup>216</sup> SDM may involve negotiation between clinicians and patients.<sup>217–220</sup> SDM is followed by a decision.

*Verification (Box F).* Verification involves establishing the accuracy of decisions; this may, in turn, affect the decision. This step may occur without intervention (eg,<sup>221</sup>) but prompting it is a major focus of CDSS error prevention, such as drug safety alerts when ordering prescriptions (eg,<sup>222</sup>).

### Part 3: Influence

*Influence of clinician characteristics (Box I).* We define clinician characteristics as attributes of the primary care provider that are brought to clinical information interactions and that alter or control the process. Clinical knowledge, contained in memory, includes 3 main types. Explicit knowledge (ie, “knowing that”) is declarative, such as knowing that a specific medication is appropriate for a given circumstance.<sup>167,200</sup> Implicit knowledge (ie, “knowing how”) is procedural knowledge related to accomplishing actions, such as referring patients to specialists.<sup>167,223</sup> Personal knowledge (“knowing who”) refers to “working knowledge” of patients,<sup>224</sup> including recollections about patients expressed as interlinked details held together in narratives.<sup>225</sup> Prior knowledge influences perceptions of case complexity and uncertainty (Line 1). Clinical knowledge is used in information processing (Box 6) through schemata (Line 2); here we represent the fact that clinician knowledge has been accumulated prior to the information interaction and is brought to bear upon it. Knowledge gaps lead to information needs (Line 3). Greater knowledge of sources<sup>201</sup> is associated with greater likelihood of question pursuit (Line 4) and PCPs’ source selections (Line 6).<sup>114,205,206</sup> Furthermore, beliefs that answers exist,<sup>32,195,201,202</sup> that sources are adequate for answers,<sup>75,94,193,201,207,210</sup> and that answers are generalizable to other patients<sup>32</sup> increase the likelihood of information-seeking (Line 4).

Technical skills affect information-seeking behavior (Line 5) and the ability to use sources (Line 5). Relevant skills include typing proficiency,<sup>226</sup> ability to interpret statistical information,<sup>109</sup> understanding of specific features,<sup>226</sup> and searching skills.<sup>79,94,109,227</sup>

*Social influence (Box II).* Social influence is a process whereby “a person’s attitudes, opinions, beliefs, or behavior are altered or controlled by . . . social communication.”<sup>228</sup>

*Patient-related social influence.* Information strategically provided by patients at their own initiative may deliberately influence information processing by highlighting details upon which clinicians (Line 7).<sup>229</sup> Patients affect decisions to seek information via requests (Line 8).<sup>32</sup> Information provided by patients about preferences is also deliberately included in SDM (Line 9).<sup>217,218,220,230</sup> PCPs’ deci-

sions about test ordering,<sup>231–233</sup> referrals,<sup>230,234–236</sup> and medication prescriptions<sup>237,238</sup> can be influenced by patient requests (Line 10). Similarly, patient resistance may influence decisions regarding testing,<sup>142,232,239</sup> referrals,<sup>234</sup> and advice provision.<sup>240</sup>

*Professional influence.* Colleagues such as other PCPs often influence decisions (Line 11),<sup>241–243</sup> as do specialists.<sup>241,243–246</sup> One mechanism for this is through the use of norms regarding how to manage patients.<sup>242</sup>

## DISCUSSION

This study introduces the CIIM, an empirically grounded process model of information interaction in primary care. The CIIM differs from prior conceptual literature in that it is empirically grounded and permits a view of the complete process of information interaction. Previous models contained less systematic documentation of their empirical basis and reflected only subparts of the process (eg, information needs,<sup>193</sup> search strategies,<sup>247</sup> source-user interactions,<sup>90</sup> or treatment decision-making<sup>124</sup>). Additionally, the model reflects research on the 3 main types of primary care clinicians, while prior models pertained only to PCPs. The synthesis provided by the CIIM can aid CDSS designers and implementers in identifying points in the process where a system is intended to intervene; such analyses may support workflow integration.

Prior to the CIIM, understanding of clinical information interaction was fragmented across multiple literatures with divergent foci. Health informatics research is typically interventional, focusing on “push” approaches, such as alerts. Information science literature typically encompasses observational studies of efforts to “pull” information (information-seeking) and access to information sources (eg,<sup>76,119,248</sup>). Literature on clinical reasoning and decision-making typically omits consideration of information interaction.<sup>249,250</sup> The integrative nature of the CIIM enables a quick grasp of relationships previously difficult to discern due to links to disparate disciplines. For example, the CIIM shows that perceived case characteristics precede both perception of information needs and type of reasoning used; these relationships were previously obscured.

The CIIM suggests potentially helpful functionality for CDSSs to support primary care. While many existing CDSSs focus on prompting and supporting verification through alerts and providing sources in context (eg,<sup>204,251</sup>), other parts of the process have received less attention. For example, information processing and evaluation are parts of the CIIM, but few interventions have supported them (see Supplementary Appendix 4). Following Trafton et al.,<sup>252</sup> an increasing design focus on “organization, prioritization, and highlighting of information” may be promising. Furthermore, building on CDSSs focused on supporting risk assessment,<sup>253–256</sup> the CIIM suggests greater support for information use through a wider range of assessments, such as probability of disease and potential benefit/efficacy of treatments.

The CIIM documents the role of influence in clinical information interaction, an important contribution, because influencers may affect the success of CDSS implementation. CDSSs that do not consider the patient-related influence may fail to anticipate issues affecting CDSS acceptance by clinicians. This highlights potential CDSS design strategies, such as incorporating information about specialist physician opinions (eg,<sup>257</sup>) or attempting to influence clinicians’ beliefs about the availability of information.

This study has limitations. Despite efforts to include studies on PAs, few were located (Supplementary Appendix 5). Additional research on this group may lead to model refinements. The aims of model development were not to explicitly elicit and characterize differences between primary care providers; future work might profitably focus on contrasts between provider types. Furthermore, the best-fit framework synthesis approach incorporates no assessment of study quality or strength of evidence for each component. Consequently, the included studies may vary in quality, and the number of supporting studies for each component may differ. To evaluate the evidence supporting the model components, we recommend consulting Supplementary Appendix 4. Furthermore, the model is constrained by the published literature itself; the CIIM will therefore exclude any part of the information interaction process that has not been described in the literature. For example, the potential role of patients' family members as information sources is underrepresented in the literature. The model is also based primarily upon research conducted in English-speaking countries. The CIIM also does not reflect new information interactions that may emerge as novel information sources and tools become available to primary care clinicians in the coming years, such as data mining, mobile sensing, and social media-based tools.

## CONCLUSION

This paper introduced the CIIM, constructed systematically based on extant literature. The model highlights 3 major components of information interaction: (1) context, (2) activity (usual and contingent), and (3) influence. The CIIM offers CDSS implementation a framework for achieving workflow integration and directions for designs supporting information interactions of diverse primary care clinicians.

## SUPPLEMENTARY MATERIAL

Supplementary material is available at *Journal of the American Medical Informatics Association* online.

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