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Reducing Delays to Diagnosis in Ambulatory Care Settings: A Macrocognition Perspective

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1. Introduction

> *"When we see things go right under difficult circumstances, we've found that it's mostly because of people's adaptive capacity—their ability to recognize, absorb, and adapt to changes and disruptions— some of which may even fall outside of what the system has been trained or designed to do."* (Dekker, Hollnagel, Woods, & Cook, p. 9)

In this paper, we overlay concepts from the theoretical framework of macrocognition upon a foundation of human factors concepts, including a perspective on how to advance patient safety known as Safety-II. The above quote represents what is now commonly referred to as the Safety-II Perspective (Hollnagel, 2018). Two perspectives on safety, called Safety-I and Safety-II, have been defined and distinguished. Safety-I is employed to restrict variability by standardizing work processes and reducing contributors to human error from biases in human judgment. Safety-II increases resilience through supportive work system design of the adaptive capacity of experts intentionally deviating during exceptional circumstances from standard procedures (Hollnagel, 2014). In Carayon and colleagues' influential Systems Engineering Initiative for Patient Safety (SEIPS) model (Carayon et al., 2006), they defined the relationships of key elements of the Safety-II perspective. These elements include how the work system factors of environment, technology, and tools, and the organization influences core work processes that, in turn, affect patient and employee outcomes. Karsh and colleagues (Karsh, Holden, Alper, & Or, 2006) extended this contribution regarding how

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system redesign can better support the physical, cognitive, and social/behavioral performance of the employee, a healthcare professional, and how better performance can improve patient and employee outcomes.

1.1 Patient harm from delays to diagnosis

Delays to diagnosis are known to harm some patients. Contributors to delays include failure or delay in ordering a diagnostic test, to establish a differential diagnosis, or to locate and assess relevant clinical information (NAS, 2015).

The rate of harm for diagnostic delays is believed to be substantial, although valid and reliable measures have not yet been fully developed or validated (Graber, 2013). In ambulatory care, the complex and evolving nature of diagnosis over time does not easily lend itself to all-purpose measures that generalize across many diseases and conditions (Lorincz et al., 2011). Delays in diagnosis can potentially be linked to increased patient mortality (Gandhi et al., 2006); for example, for patients with breast cancer, for every 5 additional years in age after diagnosis, the risk of death increases by 26%, likely due in part to delays in obtaining radiation, hormone therapy, or surgery procedures (Vidal and colleagues, 2017).

1.2 Interventions to reduce patient harm from delays to diagnosis in inpatient care

One contributor to delays is when a physician, such as a primary care provider, expresses cognitive biases, which in turn makes it easier to fixate on a single, inaccurate diagnosis. Pohl and Erdfelder (2016) define a cognitive bias as a systematic, involuntary, and difficult to avoid deviation from reality which reliably occurs. Examples of cognitive biases that may contribute to diagnostic inaccuracies and delays are the overconfidence bias, the anchoring effect, the information and availability bias, and tolerance to risk (Saposnik, Redelmeier, Ruff, & Tobler, 2016). To date, much of the focus in reducing diagnostic delays has been on how to train providers to be sensitive to the risk of biases in decision making. For example, Croskerry (2003) has proposed teaching clinicians metacognition to minimize diagnostic error through the use of cognitive forcing strategies. An example of a cognitive forcing strategy is teaching a provider about how the availability heuristic might influence making a particular diagnosis more often than is warranted by the evidence when the diagnosis is readily brought to mind. Awareness of the risk of cognitive bias has the potential to reduce delays to diagnosis, particularly with targeted training (Rudolph, Morrison, Carroll, 2009). Also, workplace strategies and forcing functions have been recommended for cognitive debiasing (Croskerry, Singhal, & Mamede, 2013).

Overall, training-based approaches have had mixed results, with effectiveness from 141 studies largely limited to trainees with low face validity scenarios and artificial environments (Graber et al., 2012). This finding is not surprising based on a human factors perspective.

In aviation, greater gains in safety have been associated with stronger corrective actions using system redesigns, such as redesigning the cockpit layout and displays, than with training or educational interventions. (Stephans, 2004; FAA, 2000). In the inpatient setting, a recent study found that the macrocognition function most mediated by technology for physicians and nurses was sensemaking (Lin et al., 2019), suggesting that redesigning technology systems could improve cognitive performance.

In the inpatient setting, there have been some interventions that go beyond training and education to reduce diagnostic delays. These interventions include:

1. expanding the role of nurses in a joint diagnostic process to have an interdisciplinary team approach to diagnosis (Gleason et al., 2017; Bunting & Groszkruger, 2016),

2. having patient loads of six patients or less for every nurse in the acute care inpatient setting (Griffiths, Ball, Murrells, Jones, & Rafferty, 2016; Aiken et al., 2014), and

3. designing the built environment to enhance cognitive performance, collaboration, and reduce distractions (O'Hara et al., 2018).

1.3 Interventions to reduce patient harm from delays to diagnosis in ambulatory care

In the outpatient setting, there has been surprisingly scant research on how to reduce patient harm. However, there are some notable exceptions. In one randomized controlled trial at 16 intervention and 9 control primary care clinics, significant improvements in documentation of abnormal results, actions, and treatment plans were achieved. The intervention included patient notifications and a 15-month learning intervention, which included a learning network, webinars, meetings, and coaching on quality improvement (Schiff et al., 2017). A working group, convened by the Agency for Healthcare Research and Quality, created a consensus document describing patient safety risks in ambulatory care settings, with a focus on medication safety (Shekelle et al., 2016). From a human factors perspective, the primary strategy put forth in this document was to monitor the rate of adverse drug events (ADEs) by employing a systems engineering approach enabled by electronic health record data (Singh et al., 2012). In this paper, we begin to provide a foundation for pursuing this strategy to achieve a reduction in ADEs, and thus delays in diagnosis.

Another set of interventions has focused on reducing interruptions, which have been documented to be a high rate in all healthcare settings, including the outpatient setting. In one study at a family practice clinic (Dearden, Smithers, & Thapar, 1996), the interruption rate for consultations was 10.2%. Most commonly, phone calls interrupted the visit; 65% of patients were unaffected by the interruption and 18% of patients had negative feelings about the interruption. A literature review conducted by Rivera-Rodriguez and Karsh (2010) criticized the bulk of interruption studies in healthcare for not studying the link between interruptions and outcomes. Their conclusion was that a high rate of interruptions "may simply be indicative of the high need for constant communication and coordination in healthcare" (Rivera-Rodriguez and Karsh, 2010, p. 314). For example, one study in their review found that pager interruptions improved ordering performance, with 51% of the interruptions leading to providers writing new medication orders (Harvey, Jarrett, & Peltekian, 1994). Interventions with a potential for improving patient safety identified by Rivera-Rodriguez and Karsh were reducing non-purposeful interruptions and limiting interruptions during high-risk procedures.

1.4 The macrocognition perspective on reducing delays to diagnosis in ambulatory care

"There are powerful regularities to be described at a level of analysis that transcends the details of the specific domain, but the regularities are not about the domain specific details, they are about the nature of human cognition and human activity" (Hutchins, 1992, cited by Woods and Hollnagel 2006, p. 3).

The above quote captures the theoretical contribution of this paper in that we build upon the human factors and system resilience concepts of Safety-II, as well as how to redesign systems to support employees. We apply the theoretical framework of macrocognition (Klein et al. 2010; Patterson et al. 2010; Patterson and Hoffman, 2012). The pressing challenge that we address in this paper is how to reduce diagnostic delays in the ambulatory care setting.

In our research (Patterson, Su, McDonald, Lisker, & Sarkar, 2017), we have identified several opportunities to enhance patient safety in ambulatory care settings. In alignment with prior human factors research (Patterson, Woods, Tinapple, & Roth, 2001), we referred to these opportunities as 'design seeds' to emphasize that the ideas are software-independent and can be combined in a modular fashion, including being integrated into existing electronic health record systems. Most of these design seeds have the potential to reduce delays in diagnosis by avoiding having patients 'fall through the cracks.' The top five out of the 12 design seeds, in the order of ranked importance by Subject Matter Experts from five specialty outpatient clinics, were:

1. keeping a patient list updated, which supports detecting problems by supporting the identification of patients who have missed appointments, and thus are at risk of delaying diagnosis and supports communicating with the primary care providers to inform that about patients who have missed appointments,
2. using triggered notifications to support detecting problems and re-planning by creating electronic notifications for pre-identified triggers; examples are that a sequence of activities has not been followed as expected, such as missed blood draws, missing lab results, or not picking up ordered medications from the pharmacy,
3. customizing the patient list to support detecting problems and coordinating,
4. controlling data access to support sensemaking, and
5. using a high-risk population registry to support all five macrocognition functions in a more resilient fashion in response to higher risks for delays to diagnosis.

1.5 Definition and illustrative examples of five macrocognition functions

Our theoretical foundation is five macrocognition functions. In Table 1, we define these five macrocognition functions and provide illustrative examples in two domains: driving and outpatient care. The purpose of the illustrative examples is to clarify how the macrocognitive functions are defined in the context of a complex task supported by technology.

In the driving example, a 30-year old male software engineer drives a car equipped with auto-pilot capability home from work. Unexpected events occur which require flexibly adapting the original route to take. In some situations, the automated support is turned off and a transition is made to manual control because the environmental conditions are outside the range of system capability.

In the outpatient care example, a 30-year old female internal medicine physician is treating a 70-year-old African American patient who is a war veteran. Achieving a timely diagnosis requires that a patient’s prescribed diagnostic pathway is navigated efficiently and safely. Pathway steps are generally structured, such as those outlined in clinical diagnosis guidelines; yet, multiple patient and systems factors often divert a patient from this pathway. In this example, a patient has not yet been diagnosed with Chronic Obstructive Pulmonary Disease. During this visit, the patient is diagnosed with another condition, depression. When the patient returns to assess the effectiveness of a newly ordered anti-depressant medication, the physician plans to assess whether the patient’s difficulty breathing has improved. In the event that the physician forgets to assess breathing or order a follow-up visit with a physician specializing in respiratory problems, or the patient experiences delays in scheduling a return visit or misses the planned visit, the diagnosis of COPD will be delayed.

2.0 Method

We designed the methodology based upon the theoretical framework of five macrocognition functions. We made the following assumptions from the beginning of this effort:

1. In the complex work setting of ambulatory care, highly trained primary care providers use sophisticated technology to collaborate to conduct complex cognitive work such as diagnosis and treatment planning.

2. When primary care providers adapt their cognition in response to the complexity of their tasks, these activities can be categorized into macrocognition functions, as originally defined by Klein and colleagues (2003).

To this end, an interdisciplinary team composed of a human factors specialist (EP), a physician with patient safety expertise (US) and a physician with informatics expertise (GS) held a series of three one-hour meetings. Prior to the first meeting, the human factors specialist distributed via email a set of draft ‘seed’ ideas for how delays to diagnosis could potentially be increased based upon suboptimal technology design. The set of ‘seed’ ideas were:

- Errors of commission occur more frequently than error of omission with the use of bar code medication administration
- Patients not assigned to a primary care provider may experience delays in care
- Providers who act as ‘heroes’ who do ‘hidden work’ to improve safety that is not fully compensated or incentivized can enhance patient safety
- Interoperability challenges with electronic health records, health information technology, and medical devices, may contribute to patient safety risks

- Not being able to easily know what has happened in a patient's history from fragmented documentation can lead to a loss of situation awareness
- If team members can get a sense of what you are doing by 'overhearing' or 'listening in' on your work, then they can help to detect errors and recover from them.
- The narrative is very important, and when data are displayed as unrelated and at the 'bit' level, it can be hard to construct a narrative
- Having data represented across patients, such as in population health approaches, can make it challenging to treat an individual patient
- Databases that are interoperable can impact the ability to see relationships
- Although people work in 'teams,' in some cases it is not known who the team members are and the team members do not stay the same over time
- Patients can help with their own care if they are better supported, which could reduce delays
- When redundant work is eliminated to reduce costs or increase efficiently, sometimes additional safety margins can unintentionally be eroded
- Focusing on safety-productivity (efficient) tradeoffs can inadvertently obscure tradeoffs made to improve "quality of worklife"
- The importance of 'hermeneutics' or work is easy to miss, and in particular how increasing the 'number of clicks' made by physicians can affect more than the time spent doing documentation, but also reduce the joy of the work related to directly helping and interacting with patients
- It is unlikely that patient safety challenges can be addressed by new generations of physicians more willing to do clerical-related tasks

Prior to the first meeting, the definitions for the five primary macrocognition functions from Patterson et al. (2010) were provided and reviewed at the beginning of the first meeting (see Table 1). The team was previously familiar with these concepts from prior collaborative research (Patterson, Militello, Su, & Sarkar, 2016).

At the first meeting, the team brainstormed the most challenging cognitive tasks that staff in ambulatory care, focusing on the role of the primary care provider, conducted that related to delays in diagnosis. When the brainstorming slowed down, another seed would be selected from the draft seeds to encourage more discussion. During the first meeting, the entire grid was filled in as a table by the human factors specialist real-time. The table was filled in real-time while all participants jointly viewed the table on a screen sharing teleconference software package based upon the real-time discussion, and the table was sent as a word processing document at the conclusion of the meeting for additional modifications or additions to be sent to the human factors specialist. Following the first meeting, the insights were grouped by the five macrocognition functions by the human factors specialist. The outcome from the first meeting was a table with columns in the grid composed of:

1. Column title of “Macrocognition function” with the representative entry of “Sensemaking”, which are contained in Table 1 filled out in advance,
2. Column title of “Definition” with the definitions provided in Table 1 filled out in advance,
3. Column title of “Illustrative example” with a representative entry generated during the meeting of “Coming up with a working diagnosis of lung cancer for a new patient complaint of shortness of breath,”
4. Column title of “Supportive format,” with representative entries generated during the meeting of “Narrative” and “lost the narrative”
5. Column title of “Delay contribution” with representative entries generated during the meeting of “Physicians don’t know the history from the last visit” and “Do not take histories from patients as often.”

In addition to filling in the table during the meeting, 371 words of real-time notes on the discussion in general were taken by the human factors specialist as one paragraph unstructured format. These notes were shared on the screen with participants real-time during the discussion. An example of a portion of the notes is “Patient with new heart failure and long history and spent so long talking to cardiology, EKG, so much longer than supposed to with him explaining what is going on, and rejuvenated by encounter even though 90 minutes for 20 minute visit.”

During and following this meeting, each member of the team identified relevant articles from their respective prior knowledge to use in a targeted literature review. The focus of the literature review was on identifying literature from domains other than healthcare which might be somewhat obscure and difficult for healthcare professionals to find in traditional healthcare repositories.

At subsequent meetings, the original table following the first meeting was split into Tables 1 and 2 and a hand-drawn Figure 1 was generated real-time by the team, with consensus achieved by discussion on all elements. During the consensus process, elements which did not achieve full consensus were removed from the tables. Following the series of meetings, the human factors specialist combined the insights into a first draft of the paper and Figure 1 was enhanced and augmented by the informatics specialist. The team then iterated on the tables, figure, literature review, resilience strategies, and illustrative examples in ad hoc small-group synchronous and asynchronous discussions.

3.0 Results

3.1 Complex tasks, resilience strategies, contributors to delays

In Figure 1, we depict the relationship between complex tasks, macrocognition functions, vulnerabilities, and resilience strategies. The figure highlights that vulnerabilities lead to increases in delays to diagnoses, treatment plans, and communications among interdisciplinary staff and with the patient. On the other hand, resilience strategies have the potential to reduce delays in diagnosis by catching erroneous assumptions and interpretations earlier in a patient's care journey.

In Table 2, we provide a detailed set of examples illustrating the relationship of the concepts in Figure 1. The primary contribution of this paper is a set of resilience strategies that could be supported by innovations in health information technology in future research.

As detailed in Table 2, for sensemaking, critical tasks are assessing risk factors for disease, detecting health changes and new symptoms, identifying that new medications were ordered during a recent hospital stay and understanding the intent of the order, and understanding insights gained from a recent visit to a consulting specialist physician that includes new lab or procedural results. The identified vulnerabilities could lead to missed opportunities, and ultimately delays in diagnosis. Resilience strategies include offloading documentation burdens, redesigning the exam room to support provider-patient communication, and changes or additional features in the electronic health record to support elicitation of the patient's history in their words, recording working insights that can lead to a definitive diagnosis, and providing patient, social, and environmental information that can help to reduce uncertainty and ambiguity.

For re-planning, critical tasks include recognizing that planned activities did not occur as expected. As constraints are unearthed, plans are flexibly adapted. For example, economic barriers could contribute to a patient denying the first choice for medication. Having to repeat appointments because preconditions are not met and forgetting planned activities can contribute to delays in diagnosis. Resilience strategies aimed at identifying deviations from a plan and remembering to do add-on activities would provide useful cognitive support.

For detecting problems, a critical task is following up after a pre-specified period to see if the treatment plan had the intended effect. Delays in following up at the appropriate interval can contribute to delays in diagnosis. Shared calendar features can support individuals and interdisciplinary teams in remembering to do follow-up activities at the correct time interval for individual patients.

For coordinating, a critical task is reviewing documented information in the electronic health record, and particularly past progress notes written by primary care and specialist providers, to recognize that early, often subtle signals of a problem are ongoing, and particularly when the signals are getting stronger that there is a bigger problem. For example, many symptoms of serious illness or rare diseases, in the beginning, are similar to more common, lower severity illnesses such as a cold or flu. When the problem persists as a pattern over time, then a deeper investigation into causes is warranted, and often involves more expensive testing as well as hospitalization or other interventions. When there are issues with interoperability and communicating insights during transitions in care, an opportunity to determine that more severe illness is present is missed, contributing to a delay in diagnosis. To recognize patterns, we can display data in a fashion that supports pattern recognition more easily than with long text with 'note bloat' from text included for billing and quality measure reporting purposes. When the problem is distributed across different providers, organizations, and disciplines, interoperability and access to data across 'stovepipes' are valuable.

4.0 Discussion

In this paper, we used five macrocognition functions to identify vulnerabilities in care provision in the outpatient setting that can contribute to diagnostic delays. Resilience strategies are proposed that can mitigate these vulnerabilities with work system redesign. This contribution augments an existing theoretical framework of the SEIPS model and the Safety-II Perspective, much of which was pioneered by Pascale Carayon with contributions from Bentzi Karsh, whom we honor in this Special Issue. We provided examples of how health information technology could be redesigned to make complex tasks easier. When cognitive tasks conducted by teams of interdisciplinary experts are easier, there is a lower likelihood of missed symptoms, forgotten activities, and delayed actions. These insights suggest a path forward for opportunities to reduce diagnostic delays, and ultimately, reduce patient harm.

In this paper, we focus specifically on the ambulatory care setting, thus beginning to address a gap in the patient safety literature. The macrocognition functions are particularly relevant for complex, socio-technical settings, and this effort confirms the relevance to this domain. We gained insights regarding the unique challenges of the outpatient care setting. First, primary care providers are under substantial time pressure and resource constraints, even though outpatient visits are usually scheduled in advance and address mostly chronic health concerns. Primary care providers are burdened by increasing panel sizes, shrinking appointment times, having to deal with multiple medical problems at once, and needing to address non-medical barriers to treatment plans. By the nature of being a generalist who serves as the entry point to specialist care providers, PCPs require broad expertise. PCPs need to interpret data, decipher and incorporate consultant opinions with which they may not agree, and meet complicated and burdensome documentation demands.

This effort represents a preliminary step in a line of potentially useful research for reducing patient harm by providing ideas for interventions that go beyond training or education. There are a number of limitations with our approach. The methodology relies heavily upon knowledge of a relatively obscure literature, in particular macrocognition functions. The relationship between papers and macrocognition functions typically needs to be inferred, which depends upon a deep knowledge of macrocognition and the human factors literature. Translating concepts between healthcare and non-healthcare domains can be challenging for clinicians without support from a human factors specialist. Conventional methodologies for literature reviews would have been difficult to use to accomplish our objective, in part because there is no single information repository to search, our key terms are not typically standardized, some similar terms appear different due to domain-specific language, and the relationships among the concepts are not always clearly identifiable based upon inspecting search terms. Therefore, we chose to employ a non-conventional approach to identifying relevant literature. Our process was also somewhat unique in that it was 'seeded' prior to the first meeting with a history of prior collaboration between a human factors expert and thoughtful clinicians on related topics, which enabled quickly and informally performing elicitation of cognitively challenging tasks in the outpatient care setting that relate to potential delays in diagnosis. Since our effort is a first step to create a foundation for future research, there was a heavy reliance on creativity. This creativity increases the chance of investigator bias and the likelihood that different research teams employing our method could end up with substantially different insights.

The coordinating function of macrocognition is particularly challenging for PCPs. In comparison with the driving example supported by an auto-pilot technology, the coordination demands for PCPS are much higher. PCPs must coordinate care provided by others and serve as the primary contact for patient requests. Therefore, all of the macrocognition functions require working in concert with a wide range of staff from other organizations, and with different bases of expertise. Although resilience strategies can take advantage of personnel conducting collaborative cross-checks (Patterson, Woods, Cook, & Render, 2007), there are also potential vulnerabilities introduced with coordination. Having multiple care providers increases the complexity, coupling, and dynamic elements of care provision, and this needs to be supervised. There may be weaker links among the distributed personnel who need to be given additional attention and mentorship. Also, there can be vulnerabilities in communicating well across care episodes with a primarily written medium. The multiple purposes of written documentation, including meeting the needs for billing, can also complicate communication and coordination.

We view our contribution as an example of constructing a bridge between how human factors engineers conceptualize cognitive work in a way that can suggest innovative design solutions. Innovations could provide the opportunity for providers to find more joy in the practice of medicine. Further, innovations could reduce the perception that PCPs need to constantly be hyper-vigilant to ensure that patients with chronic issues do not ‘fall through the cracks’ in-between their scheduled visits.

Across many of the resilience strategies is a common theme of increasing flexibility for primary care providers on the ‘front lines’ of care provision. This set of resilience strategies does not include standardization of work whereby a central administrator institutes an expectation that all personnel follow the same operating procedure. Many of the suggestions also suggest taking a broader perspective on the ‘user’ of health information technology than a single primary care provider during a single encounter with a patient. Resilience is achieved by taking an interdisciplinary team approach as well as supporting ‘catching’ erroneous assumptions or forgotten actions that occur asynchronously over some time by multiple team members.

Finally, we believe that our contribution is in line with our belief that substantial improvements in healthcare can be achieved by a deep partnership between engineers who are not typically embedded in hospitals as well as thoughtful clinicians who have experience with design thinking and an innovation mindset. We call for future research that continues to partner human factors experts with interdisciplinary clinicians in order to identify opportunities to reduce delays to diagnosis through system redesign, and particularly by generating health information technology innovations.

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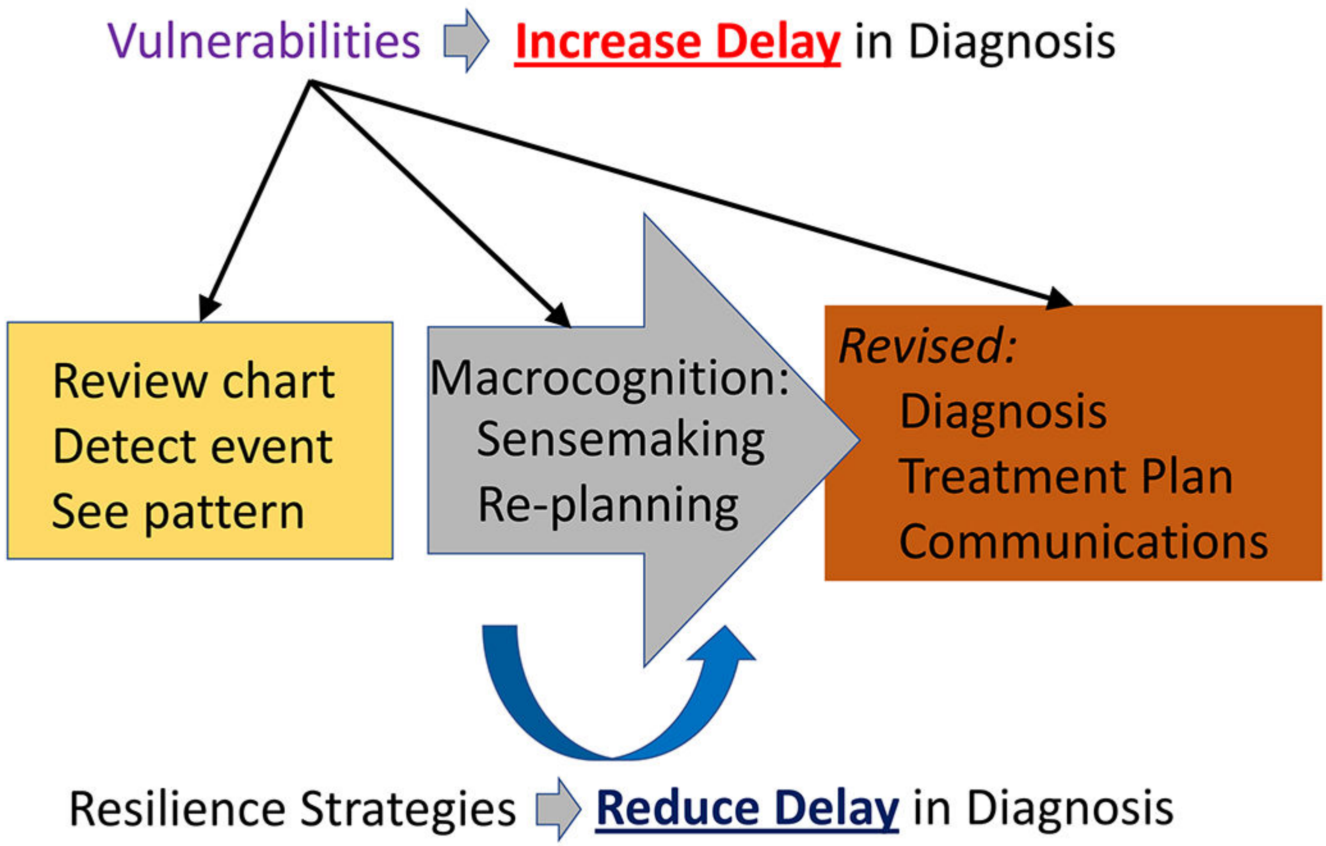

Figure 1:
Relationship of complex tasks, macrocognition functions, vulnerabilities, and resilience strategies to delays in diagnosis.

Table 1.

Five Macrognition Functions, Definitions, and Illustrative Examples

Macrocognition Function	Definition	Illustrative Example with Autopilot-Supported Driving	Illustrative Example with Primary Care Visit
Sensemaking	"Includes activities of collecting, corroborating, and integrating information and assessing how the information maps onto potential scenarios or explanations. It includes generating new potential hypotheses to consider and revisiting previously discarded hypotheses in the face of new evidence." (Patterson & Hoffman, 2012, p. 222)	The driver initiates auto-pilot and sets the destination to "home." On the way, the car leaves the intended lane based upon interpreting drifting snow as painted lanes on the road. The driver turns off auto-pilot and takes over manual control while it continues to snow to have control over how the lane boundaries are identified.	An automated algorithm flags a patient as high risk for depression based upon the home address location, income level, and living alone. The system recommends conducting a mental health screening, which the physician does during the visit. The results indicate that the patient has depression.
Re-planning	"Adaptively responding to changes in objectives, from any of a variety of sources including supervisors and peers, obstacles, opportunities, events, or changes in predicted future trajectories. When ready-to-hand default plans are applicable, there is still a need to adapt them into actions within a window of opportunity. When ready-to hand default plans do not apply to the situation, this can include creating a new strategy for building one or more goals or desired end states. This function includes adapting procedures, based on possibly incomplete guidance, to an evolving situation where multiple procedures need to be coordinated, procedures that have been started may not always be completed, or when steps in a procedure may occur out of sequence or interact with other actions" (Patterson & Hoffman, 2012, p. 222)	On the way home, a planned turn onto a road is blocked by a construction barrier because a leaking fire hydrant has created icy conditions on the road. An alternative route is taken to reach home.	Based on the new diagnosis of depression, the physician orders anti-depressant medications and adds depression to the patient's problem list in the electronic health record.
Detecting problems	"Noticing that events may be taking an unexpected direction. Whether positive or negative concerning goal accomplishment, change requires explanation and might signal a need or opportunity to reframe how a situation is conceptualized (sensemaking)and revise ongoing plans (re-planning) in progress (executing)." (Patterson & Hoffman, 2012, p. 222)	A child runs in front of the car to chase a stray ball. Both the auto-pilot and the driver simultaneously hit the brake to stop the car precipitously.	The physician notices that the patient is having trouble breathing without effort during the physical assessment.
Deciding	"Complex activity that should not be thought of simply as the act of committing to some course of action in order to reach certain fixed goals. Deciding can involve questioning the appropriateness of standard courses of action or default decisions. It can involve considering trade-offs in ongoing plan trajectories. It can involve sacrificing previous decisions or commitments." (Patterson & Hoffman, 2012, p. 222)	The driver takes his foot off the gas in preparation for stopping at the upcoming red light at the intersection. Because the light turns green, the driver puts his foot back on the gas once the stopped cars at the intersection have started moving.	The patient is usually seen once a year in the clinic. The physician instead recommends scheduling a visit in six weeks to assess how the anti-depressants are working and to see if the trouble breathing has improved without needing to schedule a consult with a specialist physician.
Coordinating	"Managing interdependencies of activity and communication across individuals acting in roles that have common, overlapping, or interacting (and possibly conflicting) goals." (Patterson & Hoffman, 2012, p. 222)	The driver gestures to a pedestrian to cross the street at an intersection before taking a right turn on a red light.	The physician writes a comment to the pharmacist that the anti-depressant medication is ordered to address depression.

Table 2.

Macrocognition functions, cognitive tasks, support strategies, and contributors to diagnostic delays

Complex Task	Macrocognition Function	Vulnerability	Resilience Strategies
Assess risk factors for lung cancer, detect a subtle new symptom of weight loss during a visit focused on other concerns and generate a plan to confirm a working diagnosis of lung cancer	Sensemaking	PCP has time and resource constraints and may not appreciate ass risk factors assessment, or new symptom and so misses an opportunity to make a new diagnosis	Offload documentation to a scribe during the outpatient visit to more thoroughly assess the patient for new symptoms (Sinsky et al., 2013) Design room such that PCP can face patient, maintain eye contact and optionally share a screen with the patient (Weiler et al., 2018)
A physician reviews notes before a follow-up visit with a patient who recently experienced an unexpected hospitalization. The patient was ordered a new pain medication following a surgical operation during the hospital stay.	Sensemaking	PCP misses that the new pain medication is masking symptoms, and so misses the opportunity to make a new diagnosis	Deliver patient and social/ environmental information that includes ambiguity and uncertainty in the context of clinical practice guidelines (Militello et al., 2018B)
For a returning patient, integrate narrative text from recent progress notes written by a consulting physician and data from specialized laboratory tests, while simultaneously assessing risk factors for disease	Sensemaking	PCP relies upon historical information from the chart that may be biased by an initial inaccurate diagnosis, focuses on inaccurate or distracting diagnoses, and thereby misses an opportunity to pursue a new diagnosis. PCP relies on a problem list, lab data, medication data, or other listed information on a primary screen to infer the patient's narrative (Kaplan, 2007), even when the information is incomplete, outdated, or intended for a different patient (Szeto, Coleman, Gholami, Hoffman, & Goldstein, 2002)	Training and sufficient time to elicit key elements of the medical history from the patient (Summerton, 2008) in their own words (Hampton, Harrison, Mitchell, Prichard, & Seymour, 1975) Provide annotation systems for PCP to record observations and judgments for subsets of data to support memory recall processes at future viewing times (Dimara et al., 2018)
Recognize that a patient did not do an expected activity of having blood drawn for analysis by the lab before the patient arriving for the visit	Re-planning	PCP schedules another visit with the patient to review the delayed lab results, and so delays the interpretation of the results and confirmation of a suspected diagnosis	Identify frequent deviations from nominal workflow and support real-time checklist-driven selection and associated automated documentation of deviations in progress note text (Jones, Beecroft, & Patterson, 2014)
Change a medication order for a patient to reduce costs to address an economic barrier to taking the medication	Re-planning	PCP forgets to change a medication order as requested by a patient, which results in a delay in seeing the impact of the new medication on status, and so delays the confirmation of a suspected diagnosis	Provide electronic workspace that supports remembering which patients' records were opened in which order and what tasks were done in the last session (Card, Robertson, & Mackinlay, 1991)
Review progress note and act on prior decision to call the patient three months after a visit to assess changes in the treatment plan	Detecting problems	No one at a clinic remembers to call a patient three months after an appointment to assess how effective a new medication was in addressing shortness of breath	Support shared calendars where reminders integrate with email, can easily be used within an organization-wide infrastructure, and have versatile functionality (Palen & Grudin, 2003)
Integrate knowledge of past patterns documented in progress notes to recognize that a pattern is continuing after a care transition	Coordinating	Missing pieces from care coordination due to EHR integration (Samal et al., 2016) or from information embedded in 'hidden text fields' that documented the progression of key data over time solely for an individual user (Patterson, 2018)	Support communication in narrative format across providers which highlights unusual patient aspects to enable continuity of care (Militello et al., 2018A) Interoperability with emergency care, urgent care, and retail clinics (Mehrotra et al., 2008)

EHR = Electronic Health Record, PCP = Primary Care Provider