Building Capacity for Health Informatics in the Future
F. Lau et al. (Eds.)

doi:10.3233/978-1-61499-742-9-167

Expert Medical Decision-Making: How the Data-Frame Theory Can Explain Physician Sense-Making

Darren HUDSON[a], Gurmeet SINGH[a,1]
[a] *University of Alberta, AB, Canada*

Abstract. The major task of physicians is decision making. This is often done in time pressured situations. The traditional theory of decision making does not reflect this reality and naturalistic decision making is a more appropriate model. The first step is to make sense of the patient or the problem and the Data-Frame Theory of Klein seems to be the best model. This model has significant implications in the way we view clinical information systems, communication and medical education.

Keywords. Medical decision making, Naturalistic decision making, Data-frame theory

1. Introduction

A physician has many responsibilities but the most fundamental role is decision maker. The act of diagnosis is a decision made about the patient's presenting problem. Decisions are often made in sub- optimal conditions. Physicians frequently operate with incomplete or incorrect information in a distracting environment. But to make at decision, a physician first must make sense of the patient.

Originally described by Karl Weick [1], sense-making is the process of providing structure to the unknown and requires the agent to place individual stimuli or data into a framework. Once the data is coherently structured, decision making can proceed.

Most research into medical decision-making has been in the context of cognitive errors and biases [2]. This is usually studied in a lab on discrete decisions. Macro cognition, on the other hand, seeks to understand the totality of mental processes leading to a decision made in a naturalistic environment [3]. This approach was developed by Klein [4] and called naturalistic decision making. In the approach is the need to first make sense before deciding. This is followed by mental model development, testing, and problem detection.

They discovered that the expert decision-maker usually only had one option in mind, without an exhaustive list of choices. There is an analogous process used by experienced clinicians: expert clinicians will only generate two or three possible diagnoses [5]. Thus, it appears that expert clinicians use the same mental processes that Klein has described.

[1] Corresponding author: Darren Hudson; Email: dhudson@ualberta.ca

2. The Data Frame Theory

Klein then expanded on naturistic decision making by proposing a data-frame theory for sense-making (6). This postulates that all sense-making activity is focused on bringing structure to presented data. Data needs to fit within a framework, and the data and frame form a complex to help make sense of the world. While data can be defined as a single point or fact, some data can be chunked from multiple data points. A frame is essentially a container for data to reside within. Fundamental to the theory is the bidirectional relationship between the data and the frame. Klein [6] describes this relationship as the frame is created by the data, but the structure of the frame also influences the search for other data (Figure 1).

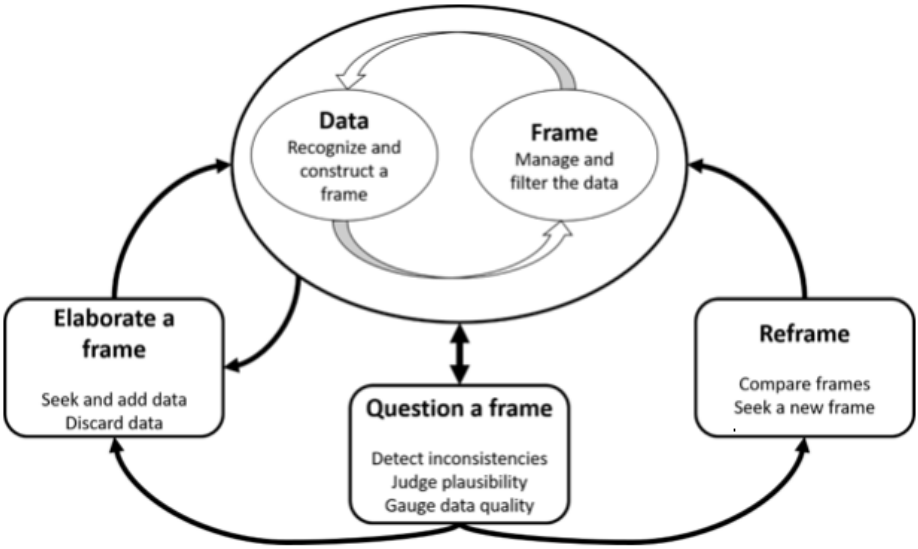

Figure 1: The Data-Frame model of sense-making (modified from Klein [6])

As an illustration, consider a jigsaw puzzle. Each piece represents an individual data point. As the pieces come together, the composition of the puzzle (frame) takes shape. The puzzle is defined by the pieces, and the puzzle cannot exist without the pieces. The evolution of the puzzle also directs the search for specific pieces. Thus, the frame is defined by the structure and relationship of the data, but the structure of the frame also directs the search for data for the frame. When the data and the frame fit together in a coherent form, the process of sense-making is complete.

People can formulate a frame using only a few data points [7]. This is because humans can only manage four objects in working memory at a time [8]. If a frame is large and requires many complex data points, this exceeds the capacity of working memory, failing to develop a coherent frame. The alternative is to create smaller frames in sequence.

There is a cycle between the data and the frame. If there is unexplained data, the cycle continues until they are brought into congruence. When the remaining pieces do not fit, several options are available to resolve the incongruity: frame elaboration, questioning, and comparison.

Elaborating the frame involves seeking more detail. There is a possibility that the frame is inadequate and needs to be expanded. The entire size of the puzzle needs to be enlarged to accommodate all the puzzle pieces remaining. The expansion can continue if no anomalous data are encountered. If remaining data is incongruent with the expanded frame, then another frame is needed.

Questioning the frame occurs when anomalous data is encountered that is inconsistent with the frame. Both the data and the frame need to be re-evaluated and the process restarts. This questioning can lead back to further frame elaboration.

When data can fit into two or more possible frames then they need to be compared to select the one that best fits the data. The comparison may lead to further data searching or rejection of one of the frames. For example, while solving one puzzle it is discovered that there are enough pieces to build two puzzles. These two competing puzzles must be compared, as it is possible that one of the puzzles fits within the other, or the original puzzle was assembled incorrectly. Comparing frames may be necessary to ensure all available data best fit the dominant frame. This is a method of testing the current frame, to confirm validity and ensure understanding.

3. Consequences

This theory is still new to medical science. Although there is ample literature in a variety of other disciplines, there are still few studies applying the model in medical decision making. Despite this, there are several ramifications in health information science.

Individuals have different frame repertoires and different data requirements. These differences are most obvious when communication is occurring between experienced physicians and trainees. Trainees describe a more superficial understanding of the problem and will emphasize the surface aspects to replace the ability to evoke the fundamental elements of the frame [9]. Expert clinicians, who have more developed frames, will tend not to focus on surface details. Thus, communication between an experienced clinician and trainee could miss the essential data and frames that the novice requires to make sense of the patient.

But as Klein points out, the difference between experienced clinicians and medical trainees is the repertoire of their frames and not the actual mental processes [6]. Novices are adults with mature mental processing. They do not need to learn how to think and therefore, the only difference between the expert and novice is repertoire available to be applied for sense-making. It follows that a more naturalistic approach to education is appropriate. Novices need to be exposed to a wide variety of stimuli with a guided process of deliberative feedback. Mentors need to be explicit in describing how they arrive at a decision, including identifying the appropriate data for the frame that they chose. This was explored in Juma and Goldszmidt's work on physician reasoning during case reviews. They found that experienced clinicians using sense-making to understand the presentation and then reframing to help trainees refine their understanding of the patient. They further argued that medical records should be reformatted to focus on the reason for admission, past medical history and history of presenting illness assist trainees in developing expert reasoning [10].

The data-frame theory also has implications on handover. Consider that handover is essentially the act of re-creating the data and frames within another individual. Therefore, the communication needs to be structured in a way to facilitate sense-making. This was put to practical use in 2010 when there was a higher number of unexpected deaths of

patients in Southampton, UK. As part of the investigation, the handover process was studied by Taylor [11] using the data-frame model. She found that there were different handover techniques used and these differences influenced the ability of the junior physicians to make sense of the patients and anticipate problems. She could show that the handover differences between two groups had a quantifiable effect on sense-making.

This theory also has significant consequences on clinical information systems. The instinct with electronic medical records is to display as much data as possible. This is likely misguided. Clinicians do not require a large data set when sense-making. Providing excessive amounts of data may impair decision-making, as the increased data contributes to cognitive overload with no additive benefit to sense-making. There is an interesting parallel between the physician and intelligence analysts. Both need to make decisions with incomplete information and actively search for data to complete frames. Wong and his group proposed modifying an interactive data visualization tool for intelligence based on the data-frame model [12]. They proposed integrating this tool into an electronic medical record to assist with data management and sense-making.

Beyond the need for visualization is the need for customization. Experienced clinicians have different data needs for sense-making. Clinical information systems need to be customizable by the clinician based on their unique approach to patient problems. Furthermore, an intelligent system could use machine learning to work with the clinician to identify relevant data points and, over time, evolve the display to suit them. In a sense, the computer and the human can work together to select the correct puzzle pieces to build the puzzle. An intelligent system would also be able to suggest additional puzzle pieces to help the physician in the process. Taking the results of these interactions into the aggregate can also improve the quality of clinical decision support systems by providing alerts that are more relevant to the user and flagging data points that may be important that the user has not considered.

4. Conclusion

In conclusion, we believe that the data frame theory for sense-making is the most appropriate model for medical decision-making. This theory flows from the realm of naturalistic decision-making, which we believe reflects the reality of most decision-making in medicine. Expert clinicians have a well-developed repertoire of frames into which data flows to make sense of their patient's problem. The cyclic interaction between the data and the frame drives the process towards congruence and sense-making. Decision-making occurs after sense-making has occurred. When the cycle breaks down or there is additional data that are inadequately explained by the predominant frame, the experienced clinician has a few options available, including questioning the frame, comparing frames, or elaborating the frame. Accepting this model for medical decision-making by experienced clinicians has several consequences for health information science. We would argue for an expansion of research into the area of naturalistic decision-making within healthcare, with a focus on the mental processes used by experienced clinicians.

References

[1] Weick KE. *Sense-making in Organizations*. Sage; 1995 May 31.

[2] Croskerry P. The importance of cognitive errors in diagnosis and strategies to minimize them. Acad Med **78**:8 (2003):775-80.

[3] G. Klein, K. G. Ross, B. M. Moon, D. E. Klein, R. R. Hoffman, E. Hollnagel. Macrocognition. *Intelligent Systems, IEEE*. 2003 May;18(3):81-5.

[4] G. A. Klein, R. Calderwood, A. Clinton-Cirocco. Rapid decision making on the fire ground. In *Proceedings of the Human Factors and Ergonomics Society* annual meeting 1986 Sep 1 (Vol. 30, No. 6, pp. 576-580). SAGE Publications.

[5] R. A. Miller. Medical diagnostic decision support systems--past, present, and future: a threaded bibliography and brief commentary. J Am Med Inform Assoc **1**:1 (1994),8.

[6] G. Klein, J. K. Phillips, E. L. Rall, D. A. Peluso. A data-frame theory of sense-making. In Expertise out of context: *Proceedings of the Sixth International Conference on Naturalistic Decision Making* 2007 (pp. 113-155). Psychology Press.

[7] J. L. Gold, M. N. Shadlen. The neural basis of decision making. Ann Rev Neurosci **21**:30 (2007), 535-74.

[8] G. A. Miller. The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psych Rev* **63**(2) (1956), 81-97.

[9] D. Hofstadter, D. R. Hofstadter, E. Sander. *Surfaces and Essences*. Basic Books; 2013.

[10] S. Juma, M. Goldszmidt. What physicians reason about during admission case review. *Adv Health Sci Educ* **28** (2016) 1-21.

[11] M. Taylor. *The impact of sense-making on knowledge transfer: a qualitative analysis of junior doctors' clinical handover* (Doctoral dissertation, University of Southampton).

[12] B. W. Wong, K. Xu, A. Holzinger. Interactive visualization for information analysis in medical diagnosis. In *Symposium of the Austrian HCI and Usability Engineering Group* 2011 Nov 25 (pp. 109-120). Springer Berlin Heidelberg.