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Graphical Representation of Lipid Panel: A Simplified Time-Series Data Display

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Abstract. High cholesterol is a risk factor for developing Atherosclerotic Cardiovascular Disease. Poorly designed health data displays cause an undue cognitive burden on clinicians. Simplified line graphs (i.e., sparklines) could support efficient cognitive processing and interpretation of lipid panel results. Clinical concepts for cognitive tasks assessing low-density lipoprotein laboratory results were analyzed according to their internal representations and data scale types. A sparkline external representation aligns more closely with the internal representations for mental tasks associated with identifying abnormalities and assessing trends compared to traditional tabular displays. By simplifying the health data display with sparklines, faster cognitive processing is theoretically supported.

Keywords. data visualization, human-computer interaction, qualitative methods, user-centered design methods

1. Introduction

Primary care providers (PCPs) monitor blood cholesterol levels, specifically low-density lipoprotein (LDL), to detect Atherosclerotic Cardiovascular Disease (ASCVD) [1]. Early detection of abnormally high cholesterol laboratory values provides opportunities to intervene, prevent, or slow ASCVD progression [1]. The work of PCPs is a combination of physical tasks (e.g., examining patients) and mental tasks (i.e., cognitive tasks) like clinical decision-making. PCPs use electronic health records (EHRs) to accomplish the mental tasks of clinical decision-making. EHRs contain various forms of health data that are retrieved and used by clinicians during patient care activities. Well-designed health data displays help clinicians achieve their goals efficiently, effectively, and satisfactorily [2]. Poorly designed displays in EHRs cause an undue cognitive burden on providers and do not support clinical workflow [3]. Efficiency and patient safety concerns emerge when mentally fatigued providers use suboptimal data displays to make clinical decisions [3].

1.1. Background

Designing usable health data displays requires understanding the end users, characterizing the nature of their clinical decisions, and appreciating the informational

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needs of their cognitive tasks. [2,4]. While the educational background and training of PCPs may differ, their clinical tasks of evaluating laboratory abnormalities and trends are the same. The clinical domain of ASCVD is complex and managed according to clinical guidelines and recommendations [1]. Routine laboratory monitoring of blood cholesterol levels is key to early detection and intervention. PCPs accomplish this goal through a lipid panel laboratory test that measures blood levels of total cholesterol (TC), low-density lipoprotein (LDL), high-density lipoprotein (HDL), and triglycerides (TG) [1]. PCPs view clinical laboratory data in the EHR ad hoc as results become available and during patient appointments. PCPs rapidly process the results information in the context of the clinical domain to assign meaning and concurrently execute several mental tasks to determine if intervention is necessary.

Macrocognition is the collection of cognitive processes that characterize thinking and functions in natural settings [4]. Cognition in natural settings includes decision-making, sensemaking, planning, adapting, problem detection, and coordination [4]. When PCPs review laboratory results to obtain situational awareness about the potential presence of disease, it is sensemaking [4]. Clinician macrocognition often occurs under time-constrained circumstances [3]. Traditional representations of laboratory data are in a tabular format [5]. Tables are ideal for expressing precise values, but graphs are better for visualizing trends and identifying outliers [6]. A simplified time-series graphical representation of lipid panel values could better support sensemaking during macrocognition when PCPs are trying to quickly detect abnormalities and trends requiring further investigation.

Time-series displays of laboratory data are effective representations [5,7]. Sparklines are condensed line graphs with non-data elements, such as axes labels and tick marks, removed [5]. Bauer et al. demonstrated acute care clinicians were able to assess sparklines more quickly compared to traditional tabular displays [5]. Sparklines were superior to tables because trends and relationships in the lab data were more easily perceived [5]. Reese et al. expanded on the work of Bauer et al. by displaying continuous laboratory data as time-series graphs to elucidate general design recommendations [7]. Reese et al. found that line graphs were preferable over spike and circular graphs, red was acceptable for indicating an abnormality if it was the only color used in the display, and a shaded area was preferred for a reference range [7]. While these studies were conducted in acute care settings with rapidly changing laboratory data, the findings are potentially generalizable to ambulatory care settings. PCPs also visualize lab data under time-constrained pressures and need to quickly identify outliers and assess trends [8]. PCPs have added challenges associated with reviewing lab data for multiple disease states spanning longer periods of time compared to acute care settings. This study outlines the theoretical basis for a sparklines lipid panel display to support efficient cognitive information processing to detect abnormalities and trends.

2. Methods

Well-designed health data displays consider the context of the clinical domain, the end users' goals, and the associated cognitive tasks. ASCVD treatment guidelines were reviewed to identify the key clinical concepts related to lipid panel data. The clinical concepts associated with laboratory result assessments were analyzed to characterize the relationships within and among the various lipid panel elements. Lipid panel concepts and elements were further reviewed in the context of theoretical frameworks.

2.1. Theoretical Frameworks and Methods

Using a health data display to assess lipid panel results in the context of key clinical concepts involves several cognitive tasks that can be understood using a distributed representational analysis. Distributed representations characterize cognitive tasks as information processed through internal and external representations [9]. The internal representation is in the mind and is the end user's mental construct for the cognitive task at hand [9]. External representations are physical symbols that exist in the world (e.g., on a computer screen) [9]. The internal and external representations of a cognitive task relate to the representational effect, which states how a formal structure is represented can impact the cognitive behaviors of those interpreting the representation [9].

The clinical concepts for LDL laboratory results were evaluated according to internal representation and the scale type (i.e., nominal, ordinal, interval, or ratio). External representations for LDL results were elucidated for traditional tabular displays and the proposed sparklines display. External representations for both displays were compared to each clinical concept's internal representation data scale type to evaluate how closely the external representations matched the internal representations.

The stages of human information processing (Figure 1) can be used to understand the relationship between external and internal representations [10]. Working memory and long-term memory encompass internal representations. The perception, response execution, and system environment feedback stages reflect external representations for cognitive tasks. A health data display's external representation of an internal representation is visualized at sensory processing and meaning is assessed at the perception stage [10]. Preattentive information processing occurs when the brain automatically organizes the visual world into objects and groups of objects [10]. Both preattentive processing and perception occur during the sensemaking stage of macrocognition. Color is sensed quickly in displays and is a categorical (i.e., nominal) data scale. Using color to externally represent a nominal scale internal representation capitalizes on the automaticity of preattentive information processing in the perception stage. Clinical concepts for lipid panel assessments with a nominal scale are candidates for external representation with color. The burden on working memory can be reduced by leveraging the brain's preattentive information processing [10].

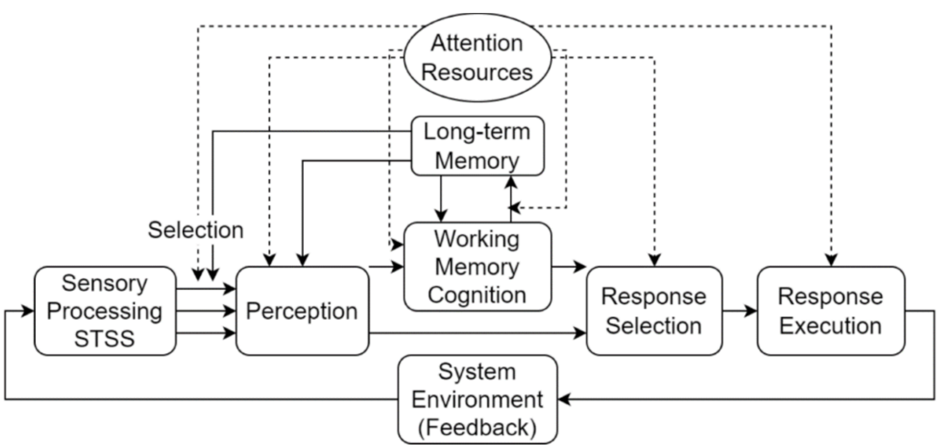

Figure 1. Stages of human information processing.

3. Results

A key clinical concept identified in the ASCVD guidelines was the LDL element of the lipid panel. LDL was clinically characterized (i.e., internally represented) in terms of normality, changes over time, and in comparison to reference ranges. For each concept, the internal representation, scale type, and external representations for a tabular and sparklines display are described in Table 1. The sparklines external representations align more closely with their respective internal representation's data scale type compared to the Arabic numbers of the tabular display's external representations. The concept of an LDL value, however, lacks an external representation in a sparklines display.

Table 1. Representations of clinical concepts for LDL cholesterol

Concept	Internal Representation	Scale Type	Tabular External Representation	Sparklines External Representation
Low-density lipoprotein	Risk factor for ASCVD	Nominal	Text, abbreviation	Text, abbreviation
LDL value (mg/dL)	Indicative of ASCVD risk	Ratio	Arabic number	n/a
LDL value range	Normal, abnormal	Nominal	Arabic number comparisons to reference range values; symbols	Color (red or black)
LDL value relative position to range	High, normal, low	Ordinal	Arabic number relative position comparison to range values; symbols	Data point above, in, or below the shaded area
LDL value trend	Improving, worsening	Ordinal	Arabic number comparisons among values	Sloped line

The sparkline external representation for the LDL clinical concepts is shown in Figure 2. The nominal concept of normality is represented by the line's color and its position with respect to the grey reference range area. Trends have an ordinal scale type (i.e., increasing, no change, decreasing), and a sloped line external representation matches the internal representation for detecting a worsening trend.

Figure 2. Sparkline display for LDL laboratory data.

4. Discussion

Using a distributed representational analysis to characterize key clinical concepts as internal and external representations reveals design opportunities to optimize health data displays for cognitive information processing. The sparklines graphical display of time-series lipid panel data efficiently represents the critical clinical concepts during sensemaking when PCPs are trying to detect abnormalities and concerning trends that warrant further investigation. Using sparklines to externally represent nominal and ordinal concepts leverages preattentive information processing. By not over-representing nominal and ordinal data with text and Arabic numbers, sparklines theoretically support faster mental processing [8].

Sparklines demonstrate theoretical promise for improved cognitive task performance when assessing lipid panel concepts with nominal and ordinal internal representations. Sparklines do not, however, accommodate internal representations of ratio scale types and cannot replace displays with specific values because providers will need precise values for certain clinical use cases. While this analysis proposes the value for a sparklines display during the sensemaking stage of macrocognition, additional work is needed to understand how the absence of precise values impacts PCPs in a clinical setting when details are needed for planning and subsequent stages of macrocognition. This type of data display requires testing and evaluation with end users in the natural environment to determine its clinical usefulness and assess the tradeoffs.

5. Conclusion

Compared to traditional tabular displays, sparklines are superior external representations for nominal and ordinal concepts because the internal representations match the scale types. Theoretically, sparklines support faster cognitive processing of critical concepts for detecting abnormalities and trends by not over-representing nominal and ordinal concepts [8]. A sparklines graphical display of time-series lipid panel data cannot replace displays with precise values because PCPs need access to detailed laboratory information. Nonetheless, a distributed representational analysis is an effective theoretical framework for characterizing internal representations according to data scale type for considering external representations designed for optimal human information processing.

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