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Conference Paper

LabTiles: An Exploratory Small-Multiples Design for Patient-Facing Blood Test Results

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Abstract

Patients increasingly access laboratory test results through digital systems, yet these are often presented as tables that are difficult for non-experts to interpret. We present LabTiles, a patient-centered visualization concept that combines reference-range information, explanatory content, and temporal context in an overview-plus-detail interface. Rather than introducing a new visual encoding, LabTiles integrates established visualization principles into a coherent workflow from report overview to parameter detail and temporal context.

We evaluated an interactive prototype with visualization experts, a general practitioner, and 19 participants. Participants generally preferred LabTiles over a conventional table and perceived its visual cues as helpful for identifying abnormal values. However, 9 of 19 participants selected a response other than the pre-specified expected action description, and the meanings associated with the colors varied. The study therefore reports preferences and exploratory design findings rather than evidence that LabTiles improves interpretation over tables.

Categories and Subject Descriptors (according to ACM CCS): Visualization [Human-centered computing]: Visualization design and evaluation methods—

1. Introduction

Patient portals increasingly provide patients with direct access to laboratory test results outside clinical settings [PRL*17]. While this can support patient-centered care and engagement [OL15, BQD*05], many patients still struggle to interpret laboratory reports and rely on clinicians for explanation [OFZF15, WZF19]. A major reason for these difficulties is that most patient portals still present laboratory results as clinician-oriented tables [ZFEW14]. Although patient-centered representations can improve communication [ZFSW*17, ZKLH21], existing approaches often focus on individual values or specific use cases.

The challenge is therefore not only to highlight abnormal values but also to provide an overview of multiple laboratory parameters while maintaining low cognitive complexity. Representations centered on a single value can reduce local complexity, but they may fragment report-level orientation and the transition to an explanation or temporal history. This challenge becomes particularly relevant when patients review laboratory reports independently before or after consultations without access to professional explanations.

To address this problem, we present *LabTiles*, a patient-centered visualization concept that combines small multiples, reference-range information, explanatory content, and temporal context in an overview-plus-detail interface. Rather than proposing a new visualization technique, the approach investigates how established visualization principles can support the exploration of laboratory reports. LabTiles is intended to support the location and contextualization of findings; it does not provide diagnoses, urgency assessments, or treatment recommendations. This work is guided by the following research questions:

RQ1: *How do participants perceive LabTiles compared with a conventional tabular laboratory report?*

RQ2: *How do participants use LabTiles and a conventional table in a scenario-based interpretation task, and what errors and limitations emerge?*

To evaluate the design, we developed an interactive prototype and conducted an exploratory evaluation with visualization experts, a general practitioner, and 19 participants. We make the following contributions:

- **LabTiles**, a patient-centered visualization concept that integrates overview, reference-range information, explanatory content, and temporal context for blood test results.

- **A design rationale** describing how established patient-centered visualization principles can be combined into a coherent laboratory-result interface.
- **An exploratory evaluation** with end users, visualization experts, and a physician, identifying opportunities and challenges for patient-facing laboratory visualizations.

2. Related Work

Research on laboratory result visualization can broadly be divided into clinician-oriented visual analytics systems and patient-facing representations of test results. Early work showed the value of graphical representations for patient status and laboratory data. Powsner and Tufte [PT94] proposed compact visual summaries for clinical communication, while Hoaglin [Hoa93] showed that certain encodings can impair perceptual accuracy. Torsvik et al. [TLM13] further found task-dependent advantages of graphical laboratory-result displays compared with traditional tables.

Several visual analytics systems, such as LifeLines [PMR*96], CareVis [AM06], and MelanomaBoard [PNB*23], support the exploration of temporal and high-dimensional clinical data, including longitudinal patient histories and clinical patterns. The survey by West et al. [WBH15] further demonstrates the value of visual analytics for electronic health records. However, these systems are designed for clinicians and often require medical knowledge and higher interaction complexity.

Patient-centered studies have addressed complementary parts of result communication. Zikmund-Fisher et al. [ZFSW*17] studied graphical emphasis of urgent and non-urgent deviations; Nystrom et al. [NSB*18] described patient-centered methods for designing test-result interfaces; Zhang et al. [ZKLH21] combined graphical results with explanations and context; and van der Mee et al. [vdMSJ*24] synthesized evidence on presentation formats, including color and reference ranges. Obenaus and Burgsteiner [OB14] presented laboratory reports with longitudinal trends, while Martinez et al. [MTR*18] investigated a disease-specific patient dashboard.

User characteristics also influence interpretation of laboratory results. Prior work has shown that graphical formats and visual cues can improve understanding, although age-related differences persist [TYQ18, TYQ19, TZQ25]. Narrative visualization research also demonstrates the value of combining visual summaries with explanatory context [MGS*22].

Evidence for small multiples is task-dependent: separate charts can support comparison across multiple time series for some tasks, while performance varies with the task and visual span [JME10]. Shneiderman's overview, filter, and details-on-demand principle provides a general framework for moving between summary and detail [Shn96]. Prior work therefore supports the individual elements used in patient-facing result communication, but provides limited evidence on their coordinated use across a multi-parameter report, parameter explanations, and temporal history.

3. Laboratory Test Results

Blood tests are commonly used for screening, diagnosis, and disease monitoring. Laboratory reports contain measured values and corresponding reference ranges, which describe expected values in a healthy population [Oza16]. However, deviations from these ranges do not necessarily indicate disease and require clinical interpretation. Moreover, laboratory values represent only a snapshot of an individual's health status, making temporal changes across repeated measurements particularly important [Oza16]. This distinction is important to communicate to patients: range status and visible change do not determine diagnosis, clinical urgency, or treatment.

4. Requirements Analysis

The design of LabTiles was informed by prior research, an analysis of current laboratory reports, and an exploratory focus group. The report analysis was a structured inspection of parameter names, measured values, units, reference ranges, abnormality flags, layout, and administrative metadata in example reports. The intended audience is adults receiving blood test results, with varying ages, medical knowledge, and digital experience. The goal was not to derive representative patient requirements but to identify challenges and design opportunities for patient-facing laboratory visualizations.

4.1. Exploratory User Analysis

To complement findings from the literature, we conducted a semi-structured focus group with eight participants (four female, four male), aged 20–25 years. Participants came from different backgrounds and had limited prior experience with laboratory reports. The session followed a workshop-style format in which participants reviewed example laboratory reports and discussed challenges related to interpretation, visual design, terminology, and information needs.

Because the focus group consisted only of younger adults, it was used to identify candidate issues rather than representative requirements. Participants consistently reported difficulties identifying relevant findings in tabular reports, relating measured values to reference ranges, and understanding medical terminology. They further expressed a preference for visual highlighting of abnormal values, contextual explanations, and support for comparing measurements over time. These observations are consistent with findings from prior work on patient-facing laboratory visualizations [ZFSW*17, ZKLH21, vdMSJ*24].

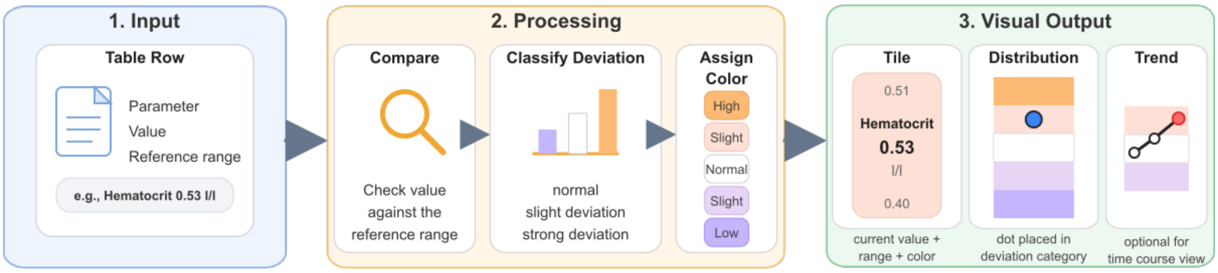


Figure 1: Overview of the LabTiles pipeline: Laboratory values are compared with reference ranges (input), classified by deviation (processing), and mapped to color-coded tiles with optional distribution and trend views (visual output).

4.2. Derived Design Requirements

Requirements were derived from the literature, report analysis, and exploratory user feedback. To keep the design focused on patient interpretation tasks, we retain only requirements that can be directly addressed by the visualization.

- **R1: Preserve essential report context** by retaining parameter names, measured values, units, and reference ranges while de-emphasizing administrative detail.
- **R2: Emphasize abnormal values** outside the reference range, including information about direction and degree of deviation [ZFSW*17, vdMSJ*24].
- **R3: Compare a value with its reference range** by displaying both in close spatial proximity.
- **R4: Move from overview to optional detail** through a report-level summary, parameter tiles, and details on demand [Shn96, ZKLH21].
- **R5: Support understandable explanations** of medical terminology for users with varying domain knowledge [ZKLH21, vdMSJ*24].
- **R6: Support temporal comparison** of measurements to identify trends and changes over time.
- **R7: Maintain low visual and interaction complexity** for users with varying levels of digital experience [WQLT25].
- **R8: De-emphasize non-essential administrative and technical information** that is primarily relevant to clinical workflows.

5. Design of LabTiles

LabTiles was developed from the requirements presented in Section 4. The system consists of two complementary views. The *Overview* supports the inspection of multiple laboratory parameters within a single report, while the *Time Course* view shows historical measurements to facilitate temporal comparison. Both views employ a tile-based small-multiples layout to provide a consistent visual structure across parameters and support comparison between values.

The intended workflow is to scan the report-level summary, inspect a parameter tile and its reference range, open an explanation when needed, and then review the same parameter in the Time Course view. The parameter name and tile structure remain consistent across these steps.

5.1. System Overview

Figure 1 illustrates the overall visualization pipeline. Laboratory parameters, measured values, and reference ranges are extracted from conventional laboratory reports and transformed into visual representations that emphasize deviations from expected ranges. The resulting interface comprises three coordinated views.

The *Person* view contains patient and administrative information that is separated from the visualizations to reduce clutter and maintain focus on result interpretation. The *Overview* view presents the current laboratory report using a compact visual representation. The *Time Course* view extends this representation by incorporating historical measurements when available.

Both visualization views use the same repeated tile structure so that each parameter retains a consistent identity across the Overview, explanation, and Time Course views.

5.2. Overview Visualization

The overview visualization (Fig. 2) combines a compact summary panel with a tile-based representation of individual laboratory parameters.

Summary panel. The left side of the interface provides a high-level overview of laboratory values grouped according to their relationship to the reference range. Values are categorized as below, within, or above the expected range, with an additional distinction between moderate and stronger deviations. The purpose of this summary is to provide an initial orientation and help users identify potentially relevant findings before inspecting individual parameters in more detail.

Parameter tiles. The primary component of the overview consists of tile-based small multiples. Each tile (Fig. 3, left) contains the parameter name, measured value, unit, and corresponding reference range. This arrangement preserves the essential information contained in conventional reports

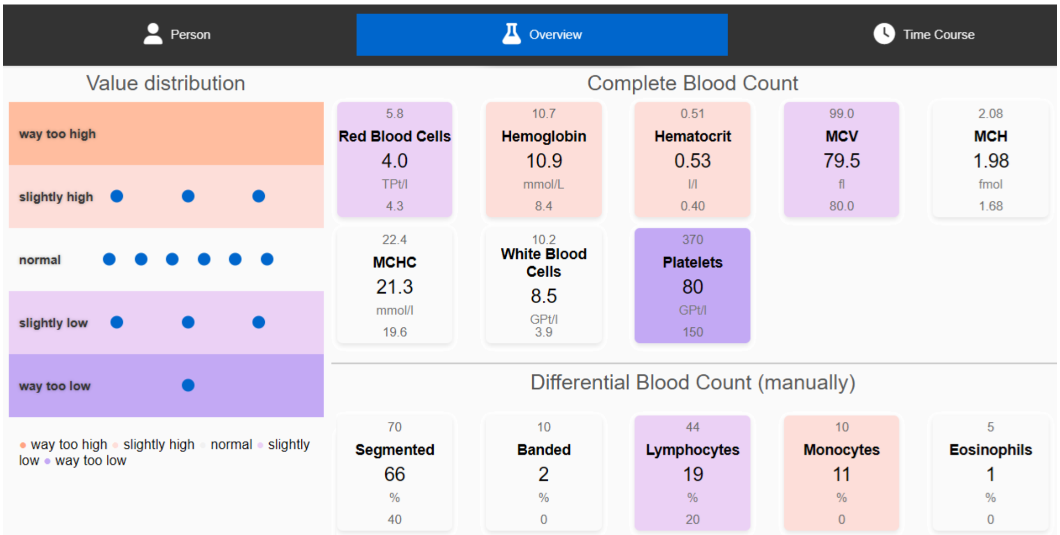


Figure 2: Overview visualization in LabTiles. Laboratory values are grouped by deviation from the reference range (left) and displayed as tile-based small multiples with value, unit, and reference range (right). Color encoding highlights abnormalities and supports comparison.

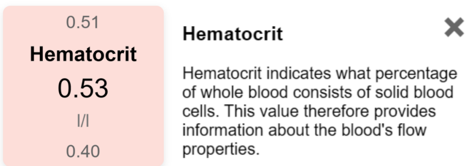


Figure 3: Tile-based visualization for hematocrit. Left: compact view showing value and reference range. Right: optional explanatory overlay providing additional context.

while placing values and reference information in close visual proximity. The repeated structure keeps each value–range pair in the same relative location across parameters.

Color encoding. Color is used to distinguish values within and outside the reference range. Values within the reference range are displayed using a neutral background, while values below and above the range are represented using different hues. Increasing color saturation indicates larger deviations from the expected range. The encoding represents the direction and magnitude of deviations consistently across views.

5.3. Time Course Visualization

The time-course view (Fig. 4) extends the overview with historical measurements while retaining the tile-based layout to ensure visual consistency and reduce context switching. Each tile visualizes recent measurements along a temporal axis (Fig. 5, left). Measurement values are represented as points connected by line segments, while colored background regions indicate whether values fall below, within, or above the reference range. Each compact tile shows up to three recent measurements.

The temporal axis reflects the chronological order of measurements and uses available timestamps when historical data are provided. By embedding temporal information directly within the tiles, the design supports comparison of multiple parameters while preserving the overview structure. Selecting a tile opens a detailed temporal view (Fig. 5, right) showing up to 20 measurements for the selected parameter.

The intended tasks are to identify the direction of recent change and reference-range crossings in compact tiles, inspect persistence or recurrence in the expanded view, and compare concurrent changes across aligned parameter tiles. These are orientation tasks; the visualization does not encode the clinical significance of a trend.

5.4. Interaction Features

LabTiles follows an overview-plus-detail strategy [Shn96]. The primary views emphasize concise visual summaries, while additional information is accessible on demand. Selecting a tile reveals explanatory information about the corresponding laboratory parameter, including a simplified description intended for non-expert users (Fig. 3, right).

To support different information needs, users can adjust tile sizes and filter parameters based on relevance. For example, values within the reference range can be temporarily hidden to focus attention on potentially relevant deviations. The measured value remains visible in every implemented

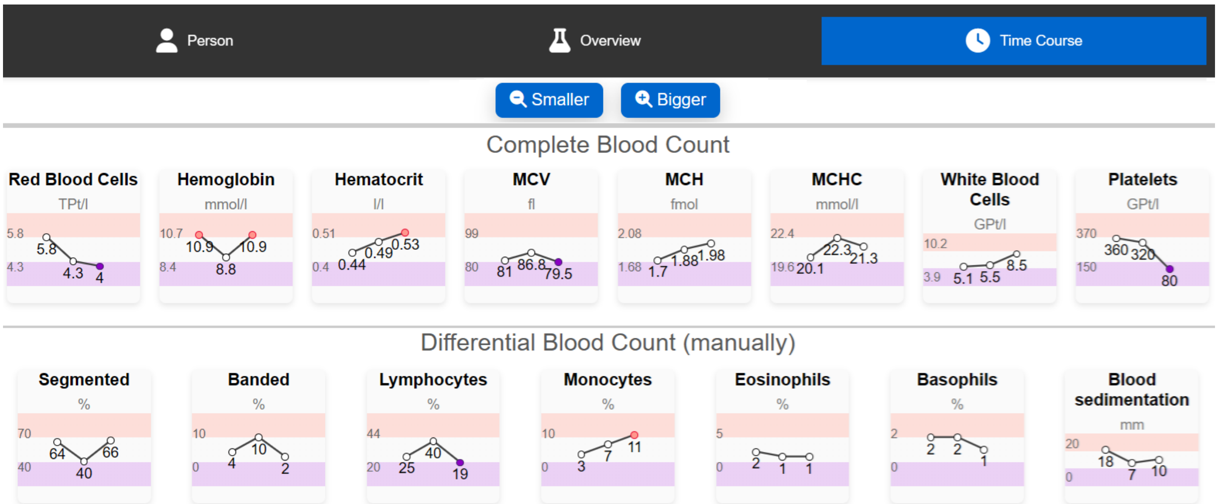


Figure 4: Time-course visualization using tile-based small multiples. Each tile contains a compact trend representation, while interaction controls support filtering and adjustment of the displayed information.

tile. An integrated onboarding tutorial introduces the interface, visual encodings, and interaction mechanisms during first use to users unfamiliar with graphical representations of laboratory data.

5.5. Implementation

Early layouts and interactions were prototyped in Figma. The evaluated prototype was implemented as a static responsive web application using vanilla HTML, CSS, and JavaScript; no general-purpose visualization library was used. HTML defines the three views and their tiles and overlays; CSS controls their visual presentation; and JavaScript maps measurements to display categories and temporal positions, while implementing navigation, filtering, tile resizing, overlays, and desktop hover linking. CSS media queries at 768 and 992 pixels adapt the navigation and the arrangement of the summary and tiles for smartphones, tablets, and desktop displays. Font Awesome supplies interface icons, and Shepherd.js implements the guided tutorial. The versioned source code and deployment instructions are available in a public GitHub repository.[†]

Explanatory texts were derived from publicly available patient-oriented laboratory information sources, such as Lab Tests Online[‡], to provide concise and accessible descriptions of laboratory values.

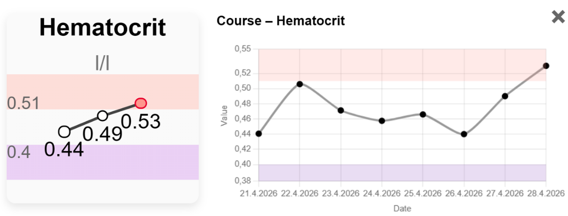


Figure 5: Detailed temporal view for a laboratory parameter. Left: compact trend view used in the overview. Right: expanded view showing the measurement history.

6. Evaluation

LabTiles was evaluated using three complementary perspectives: (1) a design review with visualization experts, (2) a semi-structured interview with a general practitioner, and (3) an exploratory user study involving 19 participants. The goal of the evaluation was not to establish clinical effectiveness, but to investigate the perceived usefulness of the design, identify strengths and weaknesses, and gather insights regarding the communication of laboratory results.

6.1. Expert Evaluation

Three visualization experts participated in an exploratory design review. The evaluation followed a think-aloud format, in which participants first reviewed a conventional laboratory report and then explored the components of LabTiles, including the overview and time-course views. The experts highlighted the visual emphasis on abnormal values, the separation of patient and laboratory information, and the use of temporal representations for comparing measurements. The

† https://github.com/LabTiles/VCBM.git
‡ https://labtestsonline.org.uk/

tile-based layout was perceived as a structured and accessible alternative to conventional tables.

The experts also identified opportunities for improvement, e.g., reducing the amount of information displayed by default and relying more strongly on progressive disclosure to reduce visual complexity. The color encoding was discussed extensively, with suggestions for alternative color schemes and stronger visual differentiation of clinically relevant abnormalities. For the time-course view, experts recommended emphasizing stronger trends and deviations while reducing visual clutter caused by redundant information.

6.2. Clinical Expert Interview

To obtain a clinical perspective, a semi-structured interview was conducted with a general practitioner. The discussion focused on communicating laboratory findings, the usefulness of the visualizations to patients, and their potential integration into routine clinical workflows.

The physician viewed the visual highlighting of abnormal values as particularly beneficial for supporting patient orientation within laboratory reports. The temporal visualizations were also perceived positively because they provide an accessible summary of changes across repeated measurements. However, a few recent measurements were considered sufficient, whereas extended histories increased perceived complexity. At the same time, the physician emphasized that visualizations should support rather than replace professional medical interpretation and consultation.

The explanatory texts were considered appropriate for patient communication and were viewed as a useful complement to laboratory values. More generally, the physician noted that patients increasingly seek additional information independently and therefore benefit from trustworthy and accessible representations of laboratory findings.

6.3. User Study

An exploratory user study was conducted with 19 participants (10 female, 9 male). All participants held at least a university entrance qualification and were recruited via convenience sampling, representing three age groups: under 30 years ($n = 9$), 30–60 years ($n = 5$), and over 60 years ($n = 5$).

The study investigated three aspects: (1) perceived usefulness and preferences, (2) how participants identified and interpreted abnormal laboratory values, and (3) perceptions of visual complexity and interaction design. All participants worked through the same hypothetical blood test scenario, in which they reviewed a laboratory report both in preparation for and during a consultation. Nine participants under 30 completed a group session using their own smartphones, while the remaining ten completed individual sessions on a tablet. Each participant received the same conventional tabular report and web prototype, explored LabTiles for 15 minutes, and subsequently compared the two representations.

The semi-structured questionnaire combined open-ended questions, forced-choice comparisons, and questions concerning clarity, informativeness, visual appeal, explanatory content, color semantics, and interaction. Participants also assessed the patient's apparent health status on a 0–9 scale and subsequently rated how certain they were about this assessment on a corresponding 0–9 confidence scale, ranging from very unsure to very sure. The forced-choice questions enabled a direct comparison between LabTiles and the table but did not capture the strength of participants' preferences.

Participants also completed two interpretation-oriented tasks based on the blood test scenario. In the action-description task, they selected one of three responses ranging from immediate medical action to no action; one response was pre-specified as expected because the scenario included a deliberately critical platelet value. They then reported whether they had relied mainly on LabTiles, the table, or both. Because both representations remained available, the results reflect self-reported use strategies rather than a controlled format comparison. A separate temporal item asked participants to classify an erythrocyte trend as an alarming decline, a striking decrease, or unremarkable. As this wording may conflate clinical severity with visual salience, the item is treated as qualitative feedback rather than a validated interpretation outcome. The full questionnaire is provided in the supplemental material.

7. Results of the User Study

This section presents the results of the user study with respect to the research questions introduced in Section 1.

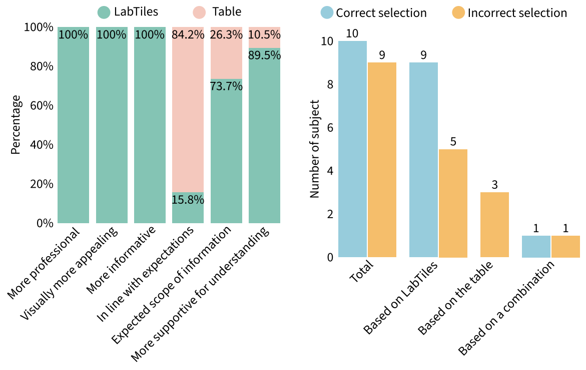
7.1. RQ1: Perceived Usefulness and Preferences

In the forced-choice comparisons, 17 of 19 participants selected LabTiles as more supportive of understanding, and all selected it as more visually appealing, professional, and informative (Fig. 6a). Participants frequently highlighted the structured layout, visual grouping of information, and clear emphasis of abnormal values.

At the same time, 84 % indicated that they would initially expect laboratory results to be presented in a tabular format, reflecting familiarity with existing clinical reports. Nevertheless, the majority perceived LabTiles as compatible with conventional laboratory reports and did not report a loss of information compared to the original table. These responses describe format preference and perceived support; they do not measure comprehension or the strength of preference.

7.2. RQ2: Interpretation Strategies and Errors

Ten participants selected the pre-specified expected action description and nine selected another response (Fig. 6b). Of the 14 participants who reported relying mainly on LabTiles, nine selected the expected response, and five did not. All



(a) Forced-choice format preferences.

(b) Scenario response by reported reliance.

Figure 6: User-study results: (a) representation preferences and (b) expected versus other action descriptions, grouped by the representation participants reported relying on.

three who reported relying mainly on the table selected another response; of the two who used both, one selected the expected response, and one did not. Separately, the health-status and confidence ratings showed no clear pattern by the representation participants reported using.

Because both representations were available and reliance was self-reported, the counts do not establish that LabTiles improves interpretation. They show that visual emphasis and close value–range coupling were not sufficient for the scenario task.

7.3. Visual Design, Color, and Temporal Views

Participants also provided qualitative feedback on the design and interaction concepts. All participants identified visually highlighted abnormalities as the most relevant elements, with color serving as the primary cue for detecting abnormal findings.

Four participants explicitly reported difficulty interpreting the color mapping. When asked which hue appeared more alarming, eight selected orange, seven selected purple, and four considered both equally alarming. The age groups showed different tendencies, but their small sizes do not support an age-dependent conclusion.

Participants also evaluated the explanatory texts and interaction mechanisms. All participants found the explanatory texts understandable, while only three preferred more detailed descriptions. When asked to compare the implemented tiles with a hypothetical alternative that would reveal the measured number only after interaction, 17 of 19 preferred keeping the number visible. Filtering and resizing were generally perceived as useful for focusing on relevant information. Several participants did not discover resizing or help functions without prompting.

In open-ended responses, several participants described the integrated overview as helpful for identifying aspects they might want to discuss with a healthcare professional. Because question generation was not assessed through a dedicated task or predefined measure, this is qualitative feedback rather than evidence of improved consultation preparation.

The compact temporal views were also viewed positively, whereas more extensive historical views received mixed feedback and were perceived as primarily useful for users interested in detailed longitudinal analysis.

8. Discussion

LabTiles provides a coherent integration and an exploratory evaluation of established components rather than a new encoding or algorithm. The preference for grouped visual cues is consistent with prior work showing that graphics and reference-range displays can make abnormalities easier to locate [ZFSW*17, vdMSJ*24]. Nevertheless, nearly half of the participants selected an action description other than the expected response despite access to both formats. This is compatible with evidence that numeracy and literacy constrain the identification of out-of-range results [ZFEW14]: visual salience cannot substitute for domain knowledge. LabTiles may support orientation and contextualization, but the study does not establish superior interpretation, improved health literacy, or safe independent clinical decisions. The open-ended comments about possible discussion topics are hypothesis-generating and require a dedicated consultation-preparation study.

The color findings separate perceptual salience from semantic meaning. Orange and purple attracted attention, but participants did not assign them a common urgency hierarchy, and the apparent age pattern is only exploratory. A color-vision-safe palette is therefore not sufficient on its own. Future designs should combine hue with explicit high/low labels, directional icons, position relative to a reference band, patterns where appropriate, and tested contrast. Evaluation should include people with color vision deficiencies, low vision, limited digital experience, and a broader age range.

LabTiles already applies overview-plus-detail to temporal data. Future work should compare alternative default history lengths, aggregation, and task-specific summaries rather than simply adding more points. More generally, small multiples avoid overlap but consume space and increase navigation demands as panels and histories grow [JME10]. Hierarchical grouping, search, user- or clinician-defined subsets, pagination or virtualization, and summaries that preserve counts of hidden abnormalities are candidate mechanisms whose effects on missed findings and navigation cost require evaluation. Scalability therefore remains unresolved.

Limitations and future work. Several limitations should be considered. The study involved a small convenience sample, and the requirements analysis was informed by a single exploratory focus group, limiting the generalizability of the findings. Furthermore, the evaluation was based on hypothetical laboratory reports and short-term interactions rather than participants' own data and real-world use. Because participants could freely consult both representations, the study provides exploratory insights into perceptions and usage patterns rather than causal evidence. The group and individual sessions also used different devices, presentation order was not counterbalanced, reliance was self-reported, and the forced-choice and scenario items were not validated instruments. Future studies should use randomized and counterbalanced conditions, Likert-type preference measures, validated comprehension and recall tasks, pre-specified scoring, larger and more diverse samples, and patient-specific data under clinical supervision.

9. Conclusion

This paper presented *LabTiles*, a patient-centered visualization concept for blood test results that integrates small multiples, reference-range information, explanatory content, and temporal context into a unified overview-plus-detail interface. Rather than introducing a new visualization technique, the work examines how these established elements can be coordinated for patient-facing report exploration.

Participants in the sample generally preferred LabTiles, but the scenario responses and varying color semantics show that preference and salience are not evidence of improved interpretation. LabTiles should therefore be understood as an exploratory design study and a basis for controlled evaluation, not as a validated clinical interpretation aid.

References

[AM06] AIGNER W., MIKSCH S.: Carevis: Integrated visualization of computerized protocols and temporal patient data. *Artificial Intelligence in Medicine 37*, 3 (2006), 203–218. doi:cbwjct. 2

[BQD*05] BALDWIN D. M., QUINTELA J., DUCLOS C., STATON E. W., PACE W. D.: Patient preferences for notification of normal laboratory test results: A report from the ASIPS collaborative. *BMC Family Practice 6*, 1 (2005), 11. doi:dnp8mm. 1

[Hoa93] HOAGLIN D. C.: Revising a display of multidimensional laboratory measurements to improve accuracy of perception. *Methods of Information in Medicine 32*, 5 (1993), 418–420. doi:q4kz. 2

[JME10] JAVED W., MCDONNEL B., ELMQVIST N.: Graphical perception of multiple time series. *IEEE Transactions on Visualization and Computer Graphics 16*, 6 (2010), 927–934. doi:dvzcst. 2, 7

[MGS*22] MEUSCHKE M., GARRISON L. A., SMIT N., BACH B., MITTENENTZWEI S., WEISS V., BRUCKNER S., LAWONN K., PREIM B.: Narrative medical visualization to communicate disease data. *Computers & Graphics 107* (2022), 144–157. doi:gt25bm. 2

[MTR*18] MARTINEZ W., THREATT A. L., ROSENBLOOM S. T., WALLSTON K. A., HICKSON G. B., ELASY T. A.: A patient-facing diabetes dashboard embedded in a patient web portal: Design sprint and usability testing. *JMIR Human Factors 5*, 3 (2018), e26. doi:gfz27h. 2

[NSB*18] NYSTROM D. T., SINGH H., BALDWIN J., SITTIG D. F., GIARDINA T. D.: Methods for patient-centered interface design of test result display in online portals. *eGEMs 6*, 1 (2018), 15. doi:gfz27q. 2

[OB14] OBENAUS M., BURGSTEINER H.: Visualization of CDA laboratory reports and long term trends as a possible EHR application for patients and physicians. In *Proceedings of eHealth* (2014), pp. 93–100. doi:q4k3. 2

[OFZF15] O'KANE M., FREEDMAN D., ZIKMUND-FISHER B. J.: Can patients use test results effectively if they have direct access? *BMJ 350* (2015). doi:gf7jvn. 1

[OL15] O'KANE M. J., LOPEZ B.: Explaining laboratory test results to patients: What the clinician needs to know. *BMJ 351* (2015). doi:gnphqn. 1

[Oza16] OZARDA Y.: Reference intervals: Current status, recent developments and future considerations. *Biochemia Medica 26*, 1 (2016), 5–16. doi:f8b7hn. 2

[PMR*96] PLAISANT C., MILASH B., ROSE A., WIDOFF S., SHNEIDERMAN B.: Lifelines: Visualizing personal histories. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (1996), pp. 221–227. doi:dgt9bz. 2

[PNB*23] PEREIRA C., NIEMANN U., BRAUN A., MIRIAM M., TUETING T., PREIM B., MEUSCHKE M.: Visual analytics to support treatment decisions in late-stage melanoma patients. In *Proceedings of Eurographics Workshop on Visual Computing for Biology and Medicine* (2023), pp. 75–85. doi:q4k2. 2

[PRL*17] PEACOCK S., REDDY A., LEVEILLE S. G., WALKER J., PAYNE T. H., OSTER N. V., ELMORE J. G.: Patient portals and personal health information online: Perception, access, and use by US adults. *Journal of the American Medical Informatics Association 24*, e1 (2017), e173–e177. doi:gjtgpn. 1

[PT94] POWSNER S. M., TUFTE E. R.: Graphical summary of patient status. *The Lancet 344*, 8919 (1994), 386–389. doi:fhj577. 2

[Shn96] SHNEIDERMAN B.: The eyes have it: A task by data type taxonomy for information visualizations. In *Proceedings of the IEEE Symposium on Visual Languages* (1996), pp. 336–343. doi:fwdq26. 2, 3, 4

[TLM13] TORSVIK T., LILLEBO B., MIKKELSEN G.: Presentation of clinical laboratory results: An experimental comparison of four visualization techniques. *Journal of the American Medical Informatics Association 20*, 2 (2013), 325–331. doi:f4n9k9. 2

[TYQ18] TAO D., YUAN J., QU X.: Presenting self-monitoring test results for consumers: The effects of graphical formats and age. *Journal of the American Medical Informatics Association 25*, 8 (2018), 1036–1046. doi:gdjct2. 2

[TYQ19] TAO D., YUAN J., QU X.: Effects of presentation formats on consumers' performance and perceptions in the use of personal health records among older and young adults. *Patient Education and Counseling 102*, 3 (2019), 578–585. doi:q4k4. 2

[TZQ25] TAO D., ZHANG W., QIN M.: Effects of patient-facing visualisations on the comprehension of personal health records among young and middle-older aged adults: An eye-tracking study. *Ergonomics* (2025), 1–15. doi:q4k5. 2

[vdMSJ*24] van der Mee F., Schaper F., Jansen J., Bons J., Meex S., Cals J.: Enhancing patient understanding of laboratory test results: Systematic review of presentation formats and their impact on perception, decision, action, and memory. *Journal of Medical Internet Research 26* (2024), e53993. doi:q4k7. 2, 3, 7

[WBH15] West V. L., Borland D., Hammond W. E.: Innovative information visualization of electronic health record data: A systematic review. *Journal of the American Medical Informatics Association 22*, 2 (2015), 330–339. doi:ggwwst. 2

[WQLT25] Wu Y., Qin M., Liu K., Tao D.: Presentation of personal health information for middle-older aged users: An eye tracking study. In *Human Aspects of IT for the Aged Population*. Springer, 2025, pp. 377–387. doi:rj2d. 3

[WZF19] Witteman H. O., Zikmund-Fisher B. J.: Communicating laboratory results to patients and families. *Clinical Chemistry and Laboratory Medicine 57*, 3 (2019), 359–364. doi:q4kx. 1

[ZFEW14] Zikmund-Fisher B. J., Exe N. L., Witteman H. O.: Numeracy and literacy independently predict patients' ability to identify out-of-range test results. *Journal of Medical Internet Research 16*, 8 (2014), e187. doi:f6f5ph. 1, 7

[ZFSW*17] Zikmund-Fisher B. J., Scherer A. M., Witteman H. O., Solomon J. B., Exe N. L., Tarini B. A., Fagerlin A.: Graphics help patients distinguish between urgent and non-urgent deviations in laboratory test results. *Journal of the American Medical Informatics Association 24*, 3 (2017), 520–528. doi:f93nsx. 1, 2, 3, 7

[ZKLH21] Zhang Z., Kmoth L., Luo X., He Z.: User-centered system design for communicating clinical laboratory test results: Design and evaluation study. *JMIR Human Factors 8*, 4 (2021), e26017. doi:q4k6. 1, 2, 3