ACTA TECHNICA JAURINENSIS
Vol. XX, No. Y, pp. ZZ-ZZ, 2026
10.14513/actatechjaur.00966

Research Article

Cognitive Information Systems and Visual Interfaces: Enhancing Decisions through Personalization

Attila Márton Putnoki[1,*], Tamás Orosz[1]

[1] ELTE Eötvös Loránd University, Pázmány Péter 1/C, 1117 Budapest, Hungary
*e-mail: faf2j3@inf.elte.hu

Submitted: 14/01/2026 Revised: 18/02/2026 Accepted: 19/02/2026 Published online: 06/08/2026

Abstract: The purpose of this study is to evaluate how to integrate personalization, cognitive resonance, and science into the design of dashboards to support more efficient decision-making processes and to decrease cognitive load on humans when using Decision-Support Systems (DSS). To accomplish these goals, we used a combination of survey data collected from professional decision makers along with some examples of various dashboards, the study evaluates how user-tailored interfaces; the use of color; and scientifically supported principles of visualizations affect the usability, and engagement of users with dashboards. Findings suggest that personalization aligns dashboards with user-specific needs, supporting clearer and more consistent perceived decision-making, while potentially strengthening cognitive resonance within Cognitive Information Systems (CIS) through effective Human-Computer Interaction (HCI). Furthermore, our findings indicate that scientifically valid dashboards will provide the most effective way to optimize the user experience and foster trust as well as the ability to accommodate varying levels of complexity in different and fast changing operational environments.

Keywords: Cognitive Information Systems; Cognitive Load; Personalization; Visualization; Decision Support; Human-Computer Interaction

I. INTRODUCTION

As the level of complexity increases within today's operational environment it will also increase the level of cognitive burden on those making decisions. Modern Decision-Support Systems (DSS) provide the ability to process large amounts of complex data in near real time; however, the large volumes of data being processed by DSS may contribute to cognitive overload when the design and structure of the visual interface and system outputs do not align with the human perceptual and interpretive abilities. Poorly designed visual interfaces, inconsistent design elements, and non-adaptive interaction structures can result in high levels of cognitive load on the part of the user. High levels of cognitive load result in reduced interpretability and ultimately reduced decision quality. From the perspective of Cognitive Information Systems (CIS), the purpose of providing information goes beyond simply providing data to achieve cognitive alignment between humans and machines. This means that there must be cognitive alignment between how humans interpret information and how machines present information.

Cognitive alignment is defined as cognitive resonance which referring to the degree of synchronization between system output, interface structure, and human interpretative processes that facilitates efficient understanding and action. Therefore, scientifically grounded interface design becomes not merely an aesthetic consideration, but a structural necessity for effective CIS environments.

As DSS developed, the recognition of scientific design principles as necessary for improving decision-making effectiveness was evident. One of the primary areas of focus for scientifically based design of the interface is Color theory. Research into Color theory has focused extensively on the physical and emotional responses to perceiving color. Since Goethe's early observations, researchers have established that certain colors will produce consistent physiological reactions; specifically, Goldstein found that specific colors can cause predictably measurable physiological reactions including negative arousal, cognitive orientation and overt action. Later research found that there are wavelength dependent effects on how people respond to color, which suggest that longer wavelengths are associated with warmth and arousal while shorter wavelengths are associated with relaxation [1]. Further research has demonstrated that color affects affect, cognition, and behavior, indicating that color should be viewed as a cognitively active design element rather than simply as a decorative feature [2–4].

Although extensive research exists in both Color theory and personalization within Human-Computer Interaction (HCI), these domains are typically investigated independently. Adaptive interfaces have been shown to improve usability and user engagement, while color design research has demonstrated measurable perceptual and behavioral effects. However, these strands of research are rarely examined within a unified Cognitive Information Systems framework. In particular, empirical investigations linking scientifically grounded color design, personalization mechanisms, perceived cognitive load reduction, and cognitive resonance in dashboard-based DSS remain limited.

To address this research gap systematically, the present study first conducted a structured PRISMA-based literature analysis focusing on four primary domains: Personalization, Cognitive Load, Visualization, and Decision Support. These domains provided the conceptual foundation for the formulation of the research questions and the subsequent empirical operationalization.

This study seeks to fill this void by investigating the relationships among personalization, scientifically supported color design, reduction of cognitive load, and decision-making efficiency in dashboard-based DSS. Utilizing a dual methodology consisting of both a structured literature analysis and an empirical survey evaluation, the study examines if visually optimized and user-adaptive dashboards can (i) reduce perceived cognitive load, (ii) increase perceived decision-making efficiency, (iii) enhance cognitive resonance between the user and the CIS. Research Questions:

- RQ1: Does personalization in dashboard-based Decision Support Systems positively influence perceived decision-making efficiency?
- RQ2: Can scientifically grounded color design reduce perceived cognitive load during dashboard interaction?
- RQ3: Does reduced cognitive load contribute to increased cognitive resonance between the user and the Cognitive Information System?
- RQ4: Can scientifically designed dashboards enhance perceived reliability in CIS-based decision contexts?

By integrating Color theory, personalization mechanisms, and cognitive alignment within a unified CIS-oriented framework, and by operationalizing these relationships through structured empirical measurement, this study contributes both conceptual clarification and exploratory empirical validation to the development of cognitively adaptive dashboard environments.

II. Methodology

A structured, dual-component methodological approach was adopted, combining a targeted literature review with an empirical survey to assess the impact of personalization, visualization principles, and cognitive load management on decision-making within Cognitive Information Systems. While the literature review established the theoretical foundation of the study, the empirical component operationalized the core constructs - personalization, cognitive load, cognitive resonance, and perceived decision reliability - through user-based evaluation.

To provide relevance and currency, the literature review focused on publications from 2020 to 2024 and included four primary keywords: Personalization, Cognitive Load, Visualization and Decision Support. These terms were selected as they directly aligned with the research scope and are relevant to the design of dashboards, Human-Computer Interaction and Cognitive Information Systems. Searches were performed in all of the major academic databases: Google Scholar (7 700 200), PubMed (3 111 092), SpringerLink (831 963), ScienceDirect (2 092 588), and Web of Science (380 953). The identification phase produced the annual keyword frequency values presented in **Table** 1. Keyword trend analysis from 2020 to 2024 provides insight into the changes in the research focus over time. While the Visualization and Decision Support categories had the highest number of publications in the earlier years, the numbers have been relatively

Table 1. *Annual occurrence of primary keywords and number of final selected sources*

Keywords	***2020***	***2021***	***2022***	***2023***	***2024***
Personalization	616 692	603 024	527 122	563 650	729 880
Cognitive Load	139 573	151 540	137 804	102 328	89 023
Visualization	1 040 359	1 059 852	938 333	811 640	789 168
Decision Support	1 645 675	1 399 766	1 117 339	959 164	703 210
Final Selected	**20**	**27**	**30**	**28**	**16**

stable in the latter years. The Cognitive Load category, while producing the lowest volume individually, has continued to produce a steadily declining number of publications, indicating a persistent niche interest. After initial retrieval, the dataset was reduced to only include publications where the selected keywords were found in the title. A second level of filtering was applied to the dataset by narrowing it down to only include publications where the selected keywords were found together in the title. The second level of filtering narrowed the dataset down to a total of 177 records. Prior to the screening phase, duplicate records were removed from the dataset, and then thematic screening based on the four predetermined categories was applied to identify and exclude off-topic or irrelevant publications.

The full-text versions of the remaining studies were retrieved during the eligibility assessment phase to ensure full-text availability and to confirm alignment with the conceptual and methodological focus of the research. This resulted in the elimination of 56 records, resulting in 121 studies being evaluated as part of the final evaluation phase. Studies retained after the inclusion phase underwent detailed content analysis, which included evaluating both the abstract and full-text version of the studies. Priority was placed on studies with strong academic references and when available, studies published with the approval of at least two independent reviewers.

The empirical study focused on a total of 29 business decision makers operating at strategic and tactical levels, each possessing multiple years of professional experience in decision-support environments. It was intended to obtain professional perceptions of informed decision makers, not to perform any demographic segmentation.

Three prototype dashboard versions were created based upon three different color schemes. Each version presented identical datasets and visualization structures; the only manipulated variable across prototypes was the applied color scheme representing different implementations of Color theory principles. All other structural and information aspects were held constant to allow for a controlled comparison.

Decision makers used a structured 17-question survey to evaluate the dashboards. Their responses were then aggregated and analyzed descriptively by means of percentage-based distribution and perceptual trend analysis. Due to the exploratory nature of the study and limited number of participants, no inferential statistical models were applied.

The survey instrument was designed through an operationalization process which linked the literature domains of PRISMA (Personalization, Cognitive Load, Visualization, Decision Support) to the research questions developed in this paper. These conceptual domains were then mapped to five operational perceptual constructs: Perceived Personalization Impact, Perceived Cognitive Load Reduction, Emotional Influence, Cognitive Resonance and Perceived Scientific Reliability. A summary of the literature domain-research question-construct relationship can be found in **Table 2**. This structure ensured that each survey item directly corresponded to the theoretical framework established in the preceding sections, thereby functioning as a perceptual operationalization of the proposed relationships within the Cognitive Information Systems model.

Table 2. *Operational Mapping of Literature Domains, Research Questions, and Survey Constructs*

PRISMA Domain	***Research Question***	***Operational Construct***	***Measurement Focus***	***Response Format***
Personalization	RQ1	Perceived Personalization Impact	Personality-based alignment & visual customization	Frequency / Likert
Cognitive Load	RQ2	Perceived Cognitive Load Reduction	Attention guidance, clarity, interpretative effort	Frequency / Likert
Visualization	RQ2, RQ3	Color-Structured Interpretation	Color harmony, salience, readability	Frequency / Likert
Decision Support	RQ1, RQ3	Perceived Decision Acceleration	Interpretation speed & decision clarity	Likert
Scientific Grounding	RQ4	Perceived Reliability & Trust	Reliability perception & recommendation intention	Frequency / Likert

III. COLOR THEORY AND ITS ASPECTS ON DECISION-MAKING

Color theory plays a relevant role in the design of visual interfaces by supporting clarity, understandability, and accessibility. Especially when Data visualization is involved in making strategic decisions such as in dashboards and process diagrams; the appropriate application of Color theory may contribute to reducing cognitive load, supporting focus, and directing attention toward priority items. Color theory has multiple fundamental principles that are applied in various disciplines (from Art and Design to the scientific study of Human Visual Perception) [5, 6]. Some of the primary topics in the literature regarding Color theory are:

- Color Models: RYB (Red, Yellow, Blue): Traditional Model used in art and design education for pigment mixtures. RGB (Red, Green, Blue): Used for Light-Emitting Color Mixtures (like Computer Screens). CMYK (Cyan, Magenta, Yellow, Black): Subtractive Model used for Printing Processes.
- Color Harmony: The aesthetic combination of colors to create visually appealing compositions. Examples of Color Harmonies are Complementary, Analogous, Triadic and others, and they are determined by the relationship of the colors on the color wheel.
- Color Psychology: Research into the ways in which colors influence the perceptions and behaviors of humans, particularly the psychological effects of colors on emotions.
- Perceptual Effects of Colors: The way in which colors influence the perception and attention of humans, including the effects of color constancy and color illusions.
- Functional Use of Colors: Practical applications in design, such as improving readability, highlighting information, and guiding visual navigation in both physical and digital spaces.

While Color theory defines the principles of using colors appropriately in the design field; the practical applications in the area of data visualization demonstrate how color is used to promote understanding and navigation. As demonstrated in the area of process diagrams and dashboards, the principles outlined above help in promoting the communication of visual information to users; thereby addressing problems associated with inconsistent color usage, and readability issues. In case of color usage during process diagramming, based on the there are various [7] aspects to be considered:

- Color Role in Visualization: Color can support readability and understanding of process diagrams; it can be a visual aid to differentiate between the many components and their relationship to one another.
- Challenges with Color Use today: The inconsistency or randomness of how color is applied to Process Models can decrease readability and create misunderstanding. Most existing Process Modeling Tools (BPMN, IDEF, EPC) do not provide sufficient direction for the optimal use of color in process diagrams, therefore decreasing the aesthetics and usability of the diagrams.
- Theoretical Insights on Color Usage: Color plays a significant role in the way humans visually perceive objects, helps in recognizing objects, and evokes an emotional response. Using principles of color harmony (complementary and monochromatic), such as the ones discussed above, can increase the visual appeal and effectiveness of the diagrams.
- Proposed Aspect-Oriented Auto-Coloring Approach: Presents a method to automatically color process diagrams through the consideration of different aspects of the process to improve its clarity and usability. The color will be determined by the pre-defined aspect taxonomy to ensure that the diagrams are both usable and readable.
- Key Constraints in Color Application: Context: Colors must align with corporate design guidelines. Contrast: Adequate contrast is necessary between elements for readability. Comfort: Colors should be aesthetically pleasing and maintain harmony.

Each theoretical and practical constraint may influence dashboard construction, as it can affect the decision-maker and, consequently, the decision-making process itself. As a result, it is important to understand these components when designing dashboards intended to support decision-making processes. Achieving the desired effectiveness of a dashboard through customization is possible by applying Color theory appropriately to meet the requirements of the decision maker and the environment. Color is an important element influencing a dashboard’s visual characteristics and users’ perceptions and responses. It is essential to know the target audience and the desired communication, target, while ensuring the color scheme is aligned with the brand identity [8]. The most commonly utilized color schemes in the design of dashboards [9, 10] include:

- Analogous Color Schemes: The primary color should predominate in the design while the secondary colors should draw attention to specific regions of the dashboard.
- Monochromatic Color Schemes: Monochromatic schemes produce a subtle and cohesive look and avoid overwhelming the user.

- Triadic Color Schemes: Triadic schemes create high contrast and a vibrant youthfulness, but great care is needed to balance them to prevent conflicts

Color impacts decision-making, 90% of split-second purchase choices on websites are dependent on color [11]. For dashboards, Color theory should be applied strategically to support readability, draw attention to Call-To-Action (CTA) elements, and maintain clarity across all visual components. A well-structured color scheme may support focus, guide visual attention, and contribute to user engagement with the interface [12, 13].

IV. Design Elements for Effective Dashboards

Decision-making has become much more complex, which necessitates systems to allow the presentation of data in an understandable format so that individuals can use the data to inform their decision-making. Decision Support Systems (e.g., dashboards) are designed to allow users to comprehend the data presented, and to act based upon the data. The quality of the data is important; however, equally important are the design elements that affect how the data will be understood and used by the individual using the dashboard. An effective dashboard may contribute to reducing cognitive load and may support users in focusing on high-priority elements during decision-making. Design elements such as negative space are important because they allow for a clean and organized view of the data, making it easier for the user to identify key data points [14, 15]. Typography is another element that facilitates this by supporting text legibility and consistency; typography affects the clarity of the information being conveyed and the ease with which the user can read the information. Font size, and style facilitate understanding of key pieces of information, particularly when users are looking at metrics, and/or performance indicators. Ensuring accessibility of dashboards is also important so that they function appropriately regardless of the device being used, and regardless of the user's context. Developing responsive designs, and providing compatibility with assistive technology (e.g., screen readers), provides access to the dashboards to a wider variety of users.

Design elements of a layout, such as applying natural scanning patterns (e.g., Z- pattern) [16] influence the direction of the user's attention to high priority areas of the dashboard. Grouping similar data logically together, and developing interactive filters may enhance the ability of the user to quickly find the data needed to inform their decisions. Brunyé & Gardony explain how the Z-pattern, which represents an increase in decision uncertainty, results in the observed eye-tracking measures, described above. In this sense, the concept of uncertainty refers to the level of perceptual ambiguity that participants experience when viewing visual stimuli. As the stimuli become less interpretable (i.e., more uncertain), the participants' eye-tracking metrics show a cognitive adaptation to these conditions. Participants demonstrate fewer but longer fixations of visual information, indicating a closer examination of the visual information. Saccadic movements are slower and over shorter distances, illustrating a more deliberate and cautious method of searching through the relevant visual information. Participant blink rates are lower than typical, illustrating greater concentration and less distraction from the task at hand. Pupil diameters are larger than typical, illustrating greater cognitive load and effort as the participant's brain analyzes the ambiguous or difficult-to-understand visual information. Collectively, these eye movement patterns and pupil diameter changes illustrate empirically the manner in which the human visual system responds to and processes uncertainty during decision-making activities [16, 17]. These findings support the notion that the principles discussed previously regarding Color theory may be used to design Cognitive Information Systems that deliver decision-makers the appropriate visualization to process the information in the least amount of time possible (reducing cognitive load and effort); enabling decision-makers to rely more on system-supported processing mechanisms during data interpretation [13].

V. Personalized Learning and Cognitive Resonance

User preference-based adaptation is now becoming very important in terms of dashboard layout design as dashboard layouts are evolving to be able to accommodate various user behaviors and preferences. The ability to learn from user interaction patterns will enable dashboards to prioritize access to the most commonly used functions and to adjust their layout to meet the individualized needs of each user. As a result of these advances in technology and the growing body of research that has demonstrated how certain user characteristics (such as personality) affect user experience, researchers have demonstrated that personality traits do indeed have an effect on the colors that users prefer. For example, researchers found that extroverted individuals preferred warmer colors such as red and orange while introverted individuals prefer cooler colors such as blue and green [17-20]. By utilizing this knowledge, designers create dashboards that reflect the user's disposition and therefore creates a more enjoyable and comfortable experience for the user. Color evokes a wide array of emotions and cognitive responses and also plays a major role in decision making. For example, red may be utilized to attract the user's attention to alert them to critical issues and prompt them to immediately act, while blue may assist the user in focusing on analytical activities and establish trust with the user [18, 21].

Predictive Analytics is currently shaping dashboard design through predictive analytics that allows dashboards to anticipate the user's needs and dynamically configure itself. Predictive analytics empowers dashboards to evaluate user behavior and data, and thus provide the user with a superior and more intuitive experience. Predictive analytics can determine the sections of the dashboard the user most frequently accesses, and alter the layout of the dashboard to reflect those user behaviors. Predictive analytics can also alter the colors of the dashboard to more closely align with the user's preferences, and improve overall usability and satisfaction. Predictive analytics can also automatically adjust the dashboard's features and settings to more accurately represent the user's behavior. Overall, advancements in dashboard design and development can lead to better decision making through providing the user with the ability to rapidly visualize trends and anomalies, thereby shortening the time required for the user to respond to changes in their data, and improving the user's productivity [22, 23].

Dynamic dashboards that adjust to the user's actions in real-time offer numerous advantages for personalizing dashboards. However, while dynamic components such as animations can effectively draw the user's attention to trends or other items of interest, overuse of these components can decrease usability [24]. Thus, it is essential to strike a balance between customization and simplicity when designing dashboards to prevent overwhelming the user with too much information, which can ultimately lower the usability of the dashboard. Another factor that complicates the design of dashboards is differences in color perception across cultures; different cultures assign different meanings to colors, and therefore dashboards must be created for use by a global audience [25]. Furthermore, there are differences in color preference between genders; men tend to choose darker colors and women tend to choose softer colors. To appeal to both genders and cultures, dashboards should be developed to be neutral and include features that permit users to personalize the appearance of the dashboard to fit their personal and cultural preferences, which can foster a sense of satisfaction and trust in the user [18, 26].

Sustainability is also another factor that is currently being evaluated when designing dashboards. Sustainability is a consideration in dashboard design because adopting sustainable practices can minimize the environmental effects associated with data processing. Techniques of data visualization that are optimized can improve performance and reduce power consumption, and lightweight interfaces can improve the sustainability of dashboards by decreasing loading times. Ultimately, successful dashboards can function on low-powered devices and promote both responsible technology usage and inclusion.

Cognitive resonance is central to the concept of personalization in dashboard design. Cognitive resonance refers to the degree to which the design of the dashboard and the recommendations made by the dashboard are aligned with the user's preferences and goals. High levels of cognitive resonance indicate a high level of alignment between the user and the dashboard, and therefore can enhance the quality of the decision-making process [13, 27]. Modern dashboards can evolve into powerful decision-support tools that are sensitive to culture, adaptable in real-time, sustainable, and guided by predictive analytics. When personalization is balanced with usability and ethics, dashboards can produce decisions that are both inclusive and of high-quality and build trust and engagement among users.

VI. Results and Empirical Evaluation

The empirical assessment was focused on identifying perceptual relationships between the use of personalization mechanisms, evidence-based color design, the reduction of perceived cognitive loads, cognitive resonance, and perceived reliability as they relate to decision-making processes occurring when utilizing dashboard-based Decision Support Systems. Survey instruments designed to assess the constructs identified in **Table 2** were completed by professional decision-makers to evaluate their perceptions of the operationalized constructs as described above.

Three controlled dashboard prototypes were presented to participants (**Fig. 1**). Each prototype displayed identical datasets and visualization structures, differing only in the applied color scheme. By controlling for the color schemes, researchers were able to isolate the effect of Color theory on the perception of the decision makers while keeping the information and layout of the dashboards constant. The Results section follows the same order of the four Research Questions developed in the Introduction. Survey responses will be summarized at the level of descriptive statistics to provide an overview of participant's perception of the four constructs in terms of percent distributions and agreement-based aggregation. This format will allow for a clear understanding of how well the surveyed constructs support decision making while maintaining consistency with the exploratory and non-inferential design of the current study.

Figure 1. *Illustrative dashboard examples*

1. Perceived Impact of Personalization on Decision-Making Efficiency

Although a significant number of individuals indicated a positive relationship between decision-making efficiency and the inclusion of personalized characteristics (based on personality profiles) in decision-support dashboards. A substantial majority of 82.7% of respondents reported that alignment between personality-based preferences and the configuration of dashboards will always or often enhance their decision-making efficiency. Related to relationship between decision-making efficiency and color customization, 62.1% of respondents indicated that the selected color scheme always or often supports their decision-making process. Although a majority of respondents reported a positive relationship between decision-making efficiency and color customization, the presence of some respondents who report an occasional or rare occurrence of such a relationship indicates that the relationship between color customization and decision-making efficiency may vary depending upon contextual or individual differences. When respondents were asked which of the elements support their decision-making processes they selected all of them (readability, object recognition, speed, and consistency), a total of 41.4% of respondents selected all of them. Thus, it appears that respondents do not perceive personalization as a single, isolated feature of dashboards but as an interaction of multiple visual and structural elements that collectively facilitate decision-making (**Table 3**).

Taken together, these findings suggest that there is a consistent perceptual association between personalization features and decision-support effectiveness; however, the strength of this association may vary as a function of the type of personalization mechanism used to customize the dashboard.

Average agreement across RQ1 indicators: (82.7 + 62.1 + 41.4)/3 = 62.07%. Based on the three indicators related to RQ1, the average agreement rate was about 62.1%. Since the average agreement rate was greater than 60%, this finding suggests that there is a moderate perceptual association between personalization features and decision-making efficiency.

Based on the findings of the current study, the answer to RQ1 (whether personalization in dashboard-based decision-support systems enhances perceived decision-making efficiency) is affirmative. The strong agreement among the majority of respondents with respect to the benefits of aligning the dashboard configuration with the personality profile of the respondent (82.7%) suggests that users perceive a benefit in customizing the appearance of the dashboard to reflect their unique personality characteristics. However, since the agreement rate with respect to the potential benefits of color customization (62.1%) is relatively low compared to the other indicators, this suggests that color customization may have less of an impact on decision-making efficiency than other forms of personalization.

Taken together, the overall agreement level (approximately 62%) indicates that personalization mechanisms are consistently perceived as beneficial for decision-support efficiency within the surveyed professional sample. Therefore, RQ1 is supported at a perceptual level within the methodological scope of the present exploratory study.

Table 3. *Summary of Survey Indicators for RQ1*

Indicator	***Agreement Rate (%)***
Personality-based alignment improves efficiency	82.7%
Color scheme supports decision-making	62.1%
Multiple visual elements jointly support decisions ("All of them")	41.4%

2. Perceived Impact of Scientifically Grounded Color Design on Cognitive Load Reduction

Survey responses indicate that scientifically grounded color design is consistently perceived as supporting attentional guidance and interpretative clarity in dashboard-based decision-making environments. Respondents who participated in the study were asked if the application of Color theory principles facilitated their ability to focus on important dashboard elements. A large proportion of respondents (86.2%) indicated that the application of Color theory principles facilitates their ability to focus on important dashboard elements. Additionally, respondents were asked to evaluate the effectiveness of different color categories (cool colors, e.g., blue, green, purple; warm colors, e.g., red, yellow, orange) in focusing attention to important alert indicators. A substantial majority of respondents (89.6%) evaluated the effectiveness of warm colors in focusing attention to important alert indicators as highly effective (4 or 5 on a 5-point scale). The strong agreement among respondents with respect to the effectiveness of warm colors in focusing attention to important alert indicators suggests that users perceive color-based salience mechanisms as functionally relevant for directing their attention to important information within complex visual interfaces. Respondents were also asked to evaluate the effectiveness of color-based salience mechanisms in enhancing the readability of dashboards and process diagrams. A large proportion of respondents (89.6%) indicated that the effectiveness of color-based salience mechanisms in enhancing the readability of dashboards and process diagrams is effective Respondents were also asked to evaluate the effectiveness of harmonious color application in improving the overall effectiveness of dashboards.

A large proportion of respondents (75.9%) indicated that the effectiveness of harmonious color application in improving the overall effectiveness of dashboards is high (4 or 5). Respondents were asked to evaluate the extent to which predefined pastel color schemes make dashboards difficult to interpret. A majority of respondents (51.7%) indicated that predefined pastel color schemes make dashboards difficult to interpret. This suggests that users perceive the lack of structured color principles as increasing the amount of effort required to interpret dashboard information.

Respondents were also asked to evaluate the extent to which inconsistent or arbitrary color choices result in difficulties with reading dashboard information. A majority of respondents (58.6%) indicated that inconsistent or arbitrary color choices result in difficulties with reading dashboard information. This suggests that users perceive the lack of structured color principles as increasing the amount of effort required to read dashboard information. Respondents were asked to evaluate the relative importance of balancing aesthetic appeal with functional clarity in designing the color scheme of a dashboard.

A large proportion of respondents (86.2%) indicated that balancing aesthetic appeal with functional clarity is very important in designing the color scheme of a dashboard. Respondents were also asked to evaluate the extent to which the psychological influence of colors affects their mood or behavior. A large proportion of respondents (75.9%) indicated that the psychological influence of colors has a high effect (4 or 5 on a 5-point scale) on their mood or behavior. This suggests that users perceive the psychological influence of colors as extending beyond aesthetics and affecting their cognitive engagement during interaction with a dashboard (**Table 4**)

Table 4. *Summary of Survey Indicators for RQ2*

Indicator	Agreement Rate (%)
Color harmony enhances effectiveness	75.9%
Harmonious color improves focus	86.2%
Colors influence mood	75.9%
Warm colors enhance alert salience	89.6%
Pastel schemes harder to interpret	51.7%
Effective color enhances readability	89.6%
Inconsistent colors cause issues	58.6%
Aesthetic–functional balance important	86.2%

This study has consistently shown a link between structured color design and reduced effort required to interpret information in decision-making contexts; The average agreement across the RQ2 indicators was 76.7%, and an overall high level of perceptual support (average agreement of 76.7%) for the idea that structured color design will decrease perceived cognitive load was demonstrated through the aggregated results of this study. Several of the main indicators have achieved agreement levels of over 85%. In particular, there was very little disagreement concerning better ability to maintain focus (86.2%), greater readability (89.6%), and the ability of warm colors to guide attention toward important alert indicators (89.6%). As previously noted, a number of respondents reported difficulty with predetermined pastel color schemes and inconsistency in their use of color. These findings also support the notion that structured and consistent use of color can help to minimize cognitive load. Therefore, it appears that structured and science-based color applications aid in decreasing cognitive load, increasing focus and clarity of interpretation and reducing interpretive efforts. Hence, RQ2 has been strongly supported at a perceptual level within the exploratory methodology used in this study. However, since the data collected were from the respondents' self-assessment of decreased cognitive load, as opposed to objective assessment of cognitive performance, the conclusions refer to perceived cognitive load decreases.

3. Perceived Relationship between Cognitive Load Reduction and Cognitive Resonance

Survey responses suggest a perceptual association between reduced interpretative effort and enhanced alignment between users and dashboard systems (**Table 5**). It was found that an overwhelming number of survey respondents (82.7%) agreed or strongly agreed that appropriate color selection improves understanding, speeds up the process of making decisions and helps make better decision choices. This suggests the use of structure in visual design is seen as enabling users to reduce cognitive processing while interacting with systems. Likewise, an even greater percentage of respondents (82.8%) stated they would recommend similar dashboard designs in other areas, which implies the respondents felt the visual design could be used effectively across various decision-aiding environments. In addition, 58.6% of all survey respondents reported experiencing emotional responses to visual aspects of the dashboards. Although the emotional reaction did not directly measure how well the respondent felt cognitively aligned to the systems' outputs, it suggests the design of the visual aspects of the dashboard influence the degree to which users emotionally engage with the systems. Therefore, collectively these indicators suggest that users feel the use of structure in color design is perceived as contributing to the reduction of cognitive effort and improve the interpretive coherence and engagement of users during Human-Computer Interaction.

Table 5. *Summary of Survey Indicators for RQ3*

Indicator	*Agreement Rate (%)*
Color enhances interpretation & decision quality	82.7%
Would adopt similar dashboards in other domains	82.8%
Emotional response to visuals	58.6%

The average agreement among all RQ3 indicators = 74.7%. RQ3 was designed to investigate if reduced cognitive load (i.e., the amount of mental effort required) will result in increased cognitive resonance between users and Cognitive Information Systems (CIS). The aggregated results demonstrate strong perceptual support (average agreement ≈ 74.7%) for the view that structured color design enhances interpretative clarity and decision acceleration.

Although over half (58.6%) of the respondents experienced an emotional connection to the dashboard visual design, the data were more varied among the respondents regarding emotional engagement; therefore, it appears that affective resonance may be influenced by either the individual or some context-dependent factor(s).

Overall, the findings indicate that respondents perceive a meaningful association between reduced interpretative effort and improved alignment with dashboard output. Therefore, RQ3 is supported at a perceptual level within the exploratory framework of the present study. However, as cognitive resonance was not directly measured through objective behavioral or synchronization metrics, the conclusion remains limited to perceived alignment rather than empirically validated resonance.

4. Perceived Reliability of Scientifically Grounded Dashboards in CIS

Survey responses indicate that dashboards explicitly grounded in scientific methods are perceived as delivering more reliable outcomes in decision-support contexts (**Table 6**). A majority of respondents (72.4%) reported that dashboards based on scientific principles always or often produce reliable results. This suggests that methodological transparency and evidence-based design increase confidence in system outputs. Further, 89.6% of respondents rated their likelihood of recommending scientifically-grounded dashboards as high (4 or 5 on a 5-point scale). This strong endorsement indicates that users perceive added value and credibility when decision-support systems explicitly integrate validated theoretical or methodological foundations.

Table 6. *Summary of Survey Indicators for RQ4*

Indicator	*Agreement Rate (%)*
Scientific dashboards deliver more reliable outcomes	72.4%
Would recommend scientifically grounded dashboards	89.6%

Taken together, these findings suggest that scientific grounding is perceived as increasing trust and reliability in Cognitive Information Systems.

Average agreement across RQ4 indicators: (72.4 + 89.6) / 2 = 81.0%. RQ4 asked whether scientifically-developed dashboards enhance perceived reliability in Cognitive Information Systems. The aggregate results show strong perceptual support (average agreement ≈ 81.0%) for the view that evidence-based design increases confidence in system outputs.

The majority agreement regarding reliability (72.4%) and the high level of recommendation intention (89.6%) suggest that methodological grounding contributes to perceived trustworthiness and credibility in decision-support environments. Therefore, RQ4 is supported at a strong perceptual level within the exploratory framework of the present study. However, as reliability was assessed through subjective evaluation rather than objective performance validation, the conclusion refers to perceived reliability rather than empirically verified outcome accuracy.

VII. Discussion

This study examined the combined impact of Color theory, user preference-based personalization, and structured visualization principles on dashboard-based decision support within Cognitive Information Systems (CIS). The empirical findings indicate consistent perceptual support for the proposed relationships, although the strength of this support varies across research questions.

The structured PRISMA-based literature review conducted prior to the empirical phase demonstrated increasing conceptual convergence among personalization research, visualization science, cognitive load theory, and decision-support systems. While these domains are often investigated independently, the present synthesis highlights their functional interdependence, particularly in visually mediated Human-Computer Interaction contexts. The current study contributes to this convergence by empirically examining the perceptual interplay between these domains.

Together, the PRISMA-informed theoretical framework and the construct-based survey operationalization provide a structured basis for responding to the research questions (**Table 7**).

Regarding RQ1, the results of our empirical study found that the mechanisms of personalization were moderately supported by perceptions (average agreement ≈ 62%). Personality-based alignment was strongly endorsed; however, the other customizable elements showed variable levels of agreement, suggesting that personalization effects are likely to be context- and multi-dimensional rather than uniformly experienced.

Regarding RQ2, scientifically-based color design had very strong perceptual support (average agreement ≈ 76.7%). All indicators regarding attentional guidance, readability and alert salience exceeded 85% agreement, indicating that structured use of color is largely seen as contributing to clear interpretation and a decrease in perceived cognitive effort.

Table 7. *Summary of Research Question Outcomes*

Research Question	***Average Agreement (%)***	***Perceptual Support Level***
RQ1: Personalization and efficiency	62.1%	Moderate
RQ2: Color theory and cognitive load	76.7%	Strong
RQ3: Cognitive load and cognitive resonance	74.7%	Strong
RQ4: Scientific grounding and reliability	81.0%	Strong

Concerning RQ3, the perceived connection between reduced cognitive load and cognitive resonance also had strong perceptual support (average agreement ≈ 74.7%). Respondents consistently indicated that appropriate color selection enhances interpretation and accelerates decision processes. Although emotional engagement was expressed by most users, it appears to have been somewhat variable, implying that emotional resonance may vary based on individual differences or contextual variables.

Finally, RQ4 found strong perceptual support (average agreement ≈ 81.0%) for the idea that dashboards that are grounded in scientific principles are viewed as being more reliable and trusted in decision-support settings.

The aggregated results of this study show that scientifically grounded visual principles have greater perceptual agreement than personalization mechanisms alone. Furthermore, the structure of this finding supports the structural distinction of the operational framework between personalization-driven alignment and evidence-based visual coherence as separate but interacting components in CIS environments, and supports the notion that structural design coherence may play a more universal role in the effectiveness of dashboards than individual preference alignment.

However, since all of the conclusions of this study are based on subjective evaluations and not objective measures of performance, the study illustrates the perceived alignment, clarity, and reliability of the dashboards, but does not establish cause-and-effect relationships or experimentally validated improvements in performance.

Future research phases will extend this investigation by establishing controlled experimental validation of the proposed relationships using eye-tracking analysis, reaction-time measurements, and visual uncertainty models to more accurately measure the reduction of cognitive load and visual uncertainty during Human-Computer Interaction with dashboards. These approaches are supported by existing studies in visual cognition and attention allocation, and will allow for a more rigorous testing of the proposed relationships.

In addition to the study's focus on business environments, the study's implications may also apply to a broader set of cognitive ecosystems, particularly to decision-support environments for mobility and transportation [28, 29]. In recent years, there has been a growing interest in developing intelligent transportation systems and mobility dashboards that facilitate quickly interpretable information, attentional guidance, and reduce cognitive load in safety-critical situations. Given the high level of real-time monitoring and traffic management, as well as autonomous supervision in many mobility and transport decision-support environments, the use of evidence-based color design and personalization methods could potentially increase situational awareness and improve the alignment between human operators and system output in such environments. As such, the second phase of the study will investigate the applicability of cognitive alignment methodologies in transport-oriented DSS environments using experimental methods that build on the ongoing research in mobility-related cognitive interface design.

VIII. Conclusion

The findings of this study indicate that scientifically grounded visual design principles and personalization mechanisms represent two complementary dimensions in the development of dashboard interfaces within Cognitive Information Systems. The results from the empirical analysis show moderate perceptual support for the ability of personalization to elicit positive perceptions and very strong perceptual support for a scientifically structured approach to color design to elicit perceptions of interpretive clarity, reliability and decision support effectiveness. In addition, a consistent amount of perceptual agreement was seen in structured color applications (especially related to attentional guidance, readability and reliability) across all surveys as compared to positive responses to personalization, however there were variable effects of personalization based on the context in which it is being used. These differences suggest that both visual coherence and use of evidence-based design principles may constitute a more universally perceived driver by users as methods to improve the effectiveness of dashboards than reliance on user preferences.

The study further suggests that reduced perceived cognitive load is associated with enhanced interpretative alignment between users and system outputs. Although cognitive resonance was not objectively measured, the perceptual data indicate that structured visualization principles may contribute to improved cognitive synchronization during Human-Computer Interaction.

Since the empirical component relied on subjective perception rather than behavioral or physiological measurements, the conclusions of this study are limited to perceived effectiveness and do not establish causal relationships or experimentally validated performance increases.

Therefore, future research should continue these findings through controlled experimental validation using eye-tracking analysis, reaction-time measurement, and quantitative modeling of visual uncertainty. Such approaches would allow for the objective evaluation of cognitive load reductions and would provide additional empirical support for the proposed relationship between the structure of visual design and cognitive resonance.

The primary contribution of this study lies not only in integrating personalization, Color theory-based visualization, perceived cognitive load, and cognitive resonance within a unified CIS-oriented conceptual framework, but also in operationalizing these relationships through a structured linkage between literature-derived domains, research questions, and measurable perceptual constructs. By structuring these interdependencies and supporting them with exploratory empirical evidence, the study establishes a theoretically grounded and methodologically transparent foundation for future experimental research and domain-specific applications in adaptive and safety-critical decision-support environments, including mobility and transportation systems.

AUTHOR CONTRIBUTIONS

A.M. Putnoki: Conceptualization, Writing, Review and editing.

T. Orosz: Writing, Supervision, Review and editing.

Disclosure Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ORCID

AM Putnoki https://orcid.org/0000-0003-1480-9479

T Orosz https://orcid.org/0000-0003-0595-6522

References

[1] K. Goldstein, Some experimental observations concerning the influence of colors on the function of the organism, American Journal of Physical Medicine & Rehabilitation 1 (1942) pp. 147–151. https://api.semanticscholar.org/CorpusID:84919425

[2] M. G. Frank and T. Gilovich, The dark side of self- and social perception: black uniforms and aggression in professional sports. Journal of personality and social psychology 54 (1) (1988) pp. 74–85. https://api.semanticscholar.org/CorpusID:26155742

[3] C. Cajochen, M. Münch, S. Kobialka, K. Kräuchi, R. Steiner, P. C. Oelhafen, S. Orgül, and A. Wirz-Justice, High sensitivity of human melatonin, alertness, thermoregulation, and heart rate to short wavelength light. The Journal of clinical endocrinology and metabolism 90 (3) (2005) pp. 1311–6. https://api.semanticscholar.org/CorpusID:17517237

[4] A. J. Elliot, Color and psychological functioning: a review of theoretical and empirical work, Frontiers in Psychology, vol. 6, 2015. https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2015.00368

[5] G. A. Agoston, Color theory and its application in art and design, 19, 2013.

[6] E. Wegman and Y. Said, ‘‘Color theory and design, ’Wiley Interdisciplinary Reviews: Computational Statistics, 3 (2) (2011) pp. 104–117.

[7] S. Erol, Coloring support for process diagrams: a review of color theory and a prototypical implementation, Vienna University of Economics and Business, 2015.

[8] C. S. Lanyi, Choosing effective colours for websites, Colour and Design (Second Edition) pp. 619–640, 2017. https://doi.org/10.1016/B978-0-08-101270-3.00026-6

[9] M. Tokumaru, N. Muranaka, and S. Imanishi, Color design support system considering color harmony, in 2002 IEEE world congress on computational intelligence. 2002 IEEE international conference on fuzzy systems. FUZZ-IEEE’02. Proceedings (Cat. No. 02CH37291), vol. 1. IEEE, 2002, pp. 378–383.

[10] G. Hu, Z. Pan, M. Zhang, D. Chen, W. Yang, and J. Chen, An interactive method for generating harmonious color schemes, Color Research & Application, 39 (1) (2014) pp. 70–78.

[11] Š. Lipták and D. Schüller, On-line marketing communication, 2023.

[12] M. Pérez-Montoro and L. Codina, Navigation design and SEO for content intensive websites: A guide for an efficient digital communication, 2016.

[13] A. M. Putnoki and T. Orosz, Evaluation and adaptive complexity of cognitive information systems, Acta Technica Jaurinensis, 18 (4) (2025) pp. 225–231. https://acta.sze.hu/index.php/acta/article/view/806

[14] B. Wong, Negative space, nature methods, 8 (1) (2011) pp. 1–2.

[15] F. Brachten, F. Brünker, N. Möllmann, B. Ross, and S. Stieglitz, On the ability of virtual agents to decrease cognitive load: an experimental study, Information Systems and e-Business Management, 18, (6) (2020).

[16] T. T. Brunyé and A. L. Gardony, Eye tracking measures of uncertainty during perceptual decision making, International Journal of Psychophysiology, 120, (2017) pp. 60–68. https://www.sciencedirect.com/science/article/pii/S0167876017302386

[17] L. Chen, W. Cai, D. Yan, and S. Berkovsky, Eye-tracking-based personality prediction with recommendation interfaces, User Modeling and User-Adapted Interaction, 33, (2023) pp. 121–157. https://doi.org/10.1007/s11257-022-09336-9

[18] J. Jue and J. H. Ha, Exploring the relationships between personality and color preferences, Frontiers in Psychology, 13 (2022). 1065372. https://doi.org/10.3389/fpsyg.2022.1065372

[19] D. Paulino, D. Guimaraes, A. Correia, J. Ribeiro, J. Barroso, and H. Paredes, A model for cognitive personalization of microtask design, Sensors, 23, (2023) pp. 3571. https://doi.org/10.3390/s23073571

[20] A. Carrera-Rivera, F. Larrinaga, G. Lasa, G. Martinez-Arellano, and G. Unamuno, Adaptui: A framework for the development of adaptive user interfaces in smart product-service systems, User Modeling and User-Adapted Interaction, vol. 34, (2024) pp. 1929–1980. https://doi.org/10.1007/s11257-024-09414-0

[21] F. Takahashi and Y. Kawabata, The association between colors and emotions for emotional words and facial expressions, Color Research & Application, 43 (2) (2018) pp. 247–257. https://doi.org/10.1002/col.22186

[22] M. Alhamadi, Challenges, strategies and adaptations on interactive dashboards, in Proceedings of the 28th ACM Conference on User Modeling, Adaptation and Personalization, 2020, pp. 368–371.

[23] D. Defiebre, D. Sacharidis, and P. Germanakos, A human-centered decentralized architecture and recommendation engine in siot, User Modeling and User-Adapted Interaction, 32 (2022).

[24] W. M. Watanabe, G. L. Amęndola, and F. C. Paes, Layout cross-platform and cross-browser incompatibilities detection using classification of dom elements, ACM Transactions on the Web (TWEB) 13 (2) (2019) pp. 1–27.

[25] A. Grzybowski, R. Lewicka, T. Torlińska, and B. Stelcer, Colors and their meaning in culture and psychology–a historical outline and contemporary status of color vision theories, Klinika Oczna/Acta Ophthalmologica Polonica 110 (1) (2008) pp. 116–124.

[26] C. S. Nwaimo, A. E. Adegbola, and M. D. Adegbola, Data-driven strategies for enhancing user engagement in digital platforms, International Journal of Management & Entrepreneurship Research 6 (6) (2024) pp. 1854–1868. https://doi.org/10.51594/ijmer.v6i6.1170

[27] D. Mattyasovszky-Philipp, A. M. Putnoki, and B. Molnár, The unrepeatable human mind—challenges in the development of cognitive information systems—what makes a machine human? Electronics 11 (3) (2022) 394. https://doi.org/10.3390/electronics11030394

[28] Répás, J., Downloading Modern Vehicles SD Card Data for Forensics Examination – A Case Study. In: Baranyi, P., Palkovics, L., Zöldy, M. (eds) Proceedings of the 2nd Cognitive Mobility Conference. COGMOB 23 2023. Lecture Notes in Networks and Systems 1345, 2025. Springer, Cham. https://doi.org/10.1007/978-3-031-87620-2_14

[29] Krizsik, N., Sipos, T., The Role of Cognitive Skills in Human-Vehicle Interactions at Designated Pedestrian Crossings. In: Zöldy, M. (eds) Proceedings of the 3rd Cognitive Mobility Conference. COGMOB 2024. Lecture Notes in Networks and Systems, vol 1258, 2025. Springer, Cham. https://doi.org/10.1007/978-3-031-81799-1_10