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ORIGINAL

Impact of Graphic Design on Information Retention: A Linear Mixed Models Approach to Visual Elements and Memory

Impacto del Diseño Gráfico en la Retención de Información: Un Enfoque de Modelos Lineales Mixtos sobre Elementos Visuales y Memoria

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ABSTRACT

Introduction: the effectiveness of graphic design in enhancing information retention depends largely on how visual elements are structured and perceived.
Objective: the study analyzes the impact of graphic design on information retention, using a rigorous statistical and experimental approach.
Method: through a linear mixed model, principal component analysis and artificial neural networks, several visual elements such as typography, contrast, visual hierarchy, text density, layout type and content format were evaluated.
Results: with a sample of 90 observations, the results showed that sans-serif typefaces, soft contrasts, use of icons, low text density and layouts with white space favor immediate information retention. On the other hand, advertising materials showed better performance compared to academic or infographics, possibly due to their more simplified and attractive design. Likewise, infographics stood out in long-term retention, due to their ability to integrate visual and textual content efficiently. The study also underscored the value of white space as a facilitator of cognitive processing, reducing mental overload. In sum, the findings demonstrated that design is not just aesthetics, but a strategic tool in enhancing learning.
Conclusions: it is concluded that a conscious visual design, adapted to the type of content and the cognitive profile of the user, can significantly optimize the way people absorb, process and remember information.

Keywords: Design; Information; Modeling; Typography; Visual.

RESUMEN

Introducción: la eficacia del diseño gráfico para mejorar la retención de información depende en gran medida de cómo se estructuran y perciben los elementos visuales.
Objetivo: el estudio analiza el impacto del diseño gráfico en la retención de información, utilizando un enfoque estadístico y experimental riguroso.
Método: a través de un modelo lineal mixto, análisis de componentes principales y redes neuronales artificiales, se evaluaron diversos elementos visuales como la tipografía, el contraste, la jerarquía visual, la densidad de texto, el tipo de layout y el formato del contenido.
Resultados: con una muestra de 90 observaciones, los resultados mostraron que tipografías sans-serif, suaves, uso de íconos, baja densidad de texto y layouts con espacio en blanco favorecen la retención inmediata

de información. Por otro lado, los materiales publicitarios mostraron mejor desempeño en comparación con los académicos o infográficos, posiblemente por su diseño más simplificado y atractivo. Asimismo, las infografías destacaron en la retención a largo plazo, debido a su capacidad para integrar contenido visual y textual de forma eficiente. El estudio también subrayó el valor del espacio en blanco como facilitador del procesamiento cognitivo, reduciendo la sobrecarga mental. En suma, los hallazgos demostraron que el diseño no es solo estética, sino una herramienta estratégica en la mejora del aprendizaje.
Conclusiones: se concluye que un diseño visual consciente, adaptado al tipo de contenido y al perfil cognitivo del usuario, puede optimizar significativamente la manera en que las personas absorben, procesan y recuerdan la información.

Palabras clave: Diseño; Información; Modelado; Tipografía; Visual.

INTRODUCTION

The effectiveness of graphic design in improving information retention depends largely on how visual elements are structured and perceived. The meaning attributed to each element in a visual presentation or context is often contextual, influenced by factors such as size and proximity to other elements.

This relationship between elements can significantly affect the viewer's understanding and retention of information. For example, the use of proximity and white space can serve as powerful visual tools that support learning design and storytelling by emphasising connections between different pieces of information.[1,2]

Visual hierarchy plays a crucial role in guiding viewers through content.[3] By manipulating aspects such as size, colour, and location, designers can create a clear path for users to follow, directing attention to the most critical elements. This structured approach helps ensure that important information stands out and is more likely to be retained.[4]

The design and alignment of visual elements also contribute to the overall structure of a page, which is fundamental to visual design. A well-structured layout can help break down complex information into manageable segments, making it easier for the brain to process and remember.[5,6]

First impressions are vital when it comes to visual design; an attractive design can immediately capture users' attention and motivate them to engage further with the content. Aesthetically pleasing initial views, such as landing pages, can significantly improve user engagement.[7,8]

Consistency in design elements such as colour schemes, typography, and imagery fosters a sense of familiarity and trust, making navigation more intuitive. This consistency not only improves the user experience but also promotes long-term retention of information.[9,10]

Research on cognitive encoding and memory retention has indicated that the act of drawing can improve information retrieval by engaging multiple cognitive processes.[11,12] When individuals draw concepts, they develop meanings, engage in motor actions, and visually inspect their creations, which helps encode information in memory.

The strength of these memories is often determined by the number of connections made with other existing memories; the more connections there are, the more resistant the memory becomes to forgetting.[13,14] This underscores the importance of integrating visual elements into learning experiences, as they can create richer memory pathways, leading to better information retention. Therefore, the objective of this research was to evaluate the impact of graphic design on information retention using a mixed linear model approach to visual elements and memory.

METHOD

Statistical Models

The study implements a multilevel analytical approach to understand how graphic design elements influence users' information retention and processing abilities. The analysis methodology is structured into three complementary levels:

First, a mixed linear model was used that recognises the hierarchical nature of the data, considering both the fixed effects of the design and the individual variations of the participants. This approach is particularly valuable because it allows us to understand how different people respond to the same design elements, recognising that the effectiveness of the design is not uniform for all users.

Second, main component analysis (PCA) was implemented to identify underlying patterns in the design elements. This technique helped to discover which combinations of design elements tend to work together and how these patterns can influence the user experience. It is especially useful for reducing design complexity to its most fundamental and effective elements.

Finally, an artificial neural network with a two-layer hidden architecture (100 and 50 neurons, respectively)

was used to model the non-linear relationships between design elements and learning outcomes. This deep learning approach allows for the capture of complex interactions that might go unnoticed in traditional statistical analyses.

The results were presented visually and quantitatively through:

Statistical summary tables providing an overview of central trends and variability, box and violin plots illustrating the distribution of results for each design element, correlation matrices showing the interrelationships between numerical variables, and specific visualisations for each dependent variable, allowing a detailed analysis of how each design element affects different aspects of learning.

This comprehensive analysis not only allows us to understand which design elements are most effective, but also how these elements interact with each other and how their effectiveness can vary according to the individual characteristics of users. This information is invaluable for creating more effective and personalised designs that maximise information retention and comprehension.

Data used

The study analysed the effects of graphic design on information retention using an experimental dataset comprising 90 observations. The dataset incorporates the following variables:

Independent variables (fixed effects): typography: categorised as serif and sans-serif, colour contrast: three levels (high, medium, low), visual hierarchy: implemented through headings, bold type and icons, text density: classified as high, medium and low, type of design: characterised by alignment, balance and white space, and type of material: categorised as academic, infographic and advertising.

Control variables (random effects): participant ID: unique identifier per participant, educational level: distributed into university, secondary and primary, cognitive style: classified as visual, verbal and mixed.

Dependent Variables (performance metrics): immediate retention: normal distribution (μ=70, σ=15), delayed retention: normal distribution (μ=60, σ=20), response time: normal distribution (μ=5, σ=2), recall accuracy: normal distribution (μ=80, σ=10).

RESULTS

The table of statistics on immediate retention (table 1) reveals interesting patterns about how different aspects of graphic design can influence the immediate ability to retain information.

Table 1. Immediate retention statistics

Typography Type	Sans-serif	69,07	15,03	40,19	97,78
	Serif	67,97	13,08	30,70	93,69
Color Contrast	High	67,18	13,50	41,30	93,69
	Low	70,19	14,88	30,70	93,47
	Medium	68,18	13,97	40,60	97,78
Visual Hierarchy	Bold	68,18	13,97	40,60	97,78
	Headers	67,18	13,50	41,30	93,69
	Icons	70,19	14,88	30,70	93,47
Text Density	High	67,18	13,50	41,30	93,69
	Low	70,19	14,88	30,70	93,47
	Medium	68,18	13,97	40,60	97,78
Layout Type	Alignment	67,18	13,50	41,30	93,69
	Balance	68,18	13,97	40,60	97,78
	Whitespace	70,19	14,88	30,70	93,47
Material Type	Academic	67,18	13,50	41,30	93,69
	Advertisement	70,19	14,88	30,70	93,47
	Infographic	68,18	13,97	40,60	97,78

Below is a qualitative interpretation of the most relevant results

1. Typography Type:

Texts presented in sans-serif fonts showed a slight advantage in immediate retention (69,07) compared to serif fonts (67,97). This suggests that cleaner, more modern fonts facilitate faster and more comprehensible

reading in the short term. In contrast, although traditionally associated with prolonged reading, serif fonts do not please immediate retention as much.

2. Colour contrast:

Low contrast was associated with the highest average retention (70,19), which is counterintuitive, as high contrast is often recommended to improve readability. However, this could indicate that excessive contrast causes visual fatigue or distraction, while soft contrast could promote more fluid reading and, therefore, greater retention.

3. Visual Hierarchy:

Designs that used icons as a means of hierarchy achieved the best results (70,19) compared to headings (67,18) and bold text (68,18). This suggests that symbolic graphic elements facilitate visual encoding and association with meanings, which improves retention.

4. Text Density:

Designs with low text density achieved the highest retention (70,19), while those with high density achieved the lowest (67,18). This supports the idea that more spaced-out, clear, and concise text allows the reader to process and retain information more effectively.

5. Layout Type:

Layouts with white space led the way in retention (70,19), confirming that strategic use of space promotes visual organization and reduces cognitive overload. In contrast, designs focused solely on alignment were less effective (67,18).

6. Material Type:

Surprisingly, advertisements achieved higher retention levels (70,19) than academic materials (67,18) and infographics (68,18). This could be because ads are designed with more attractive and simplified visual techniques, facilitating attention and immediate memorization.

The Influence of Design on Learning Ability: A Journey Through the Data

Figure 1. Confusion matrix for data obtained

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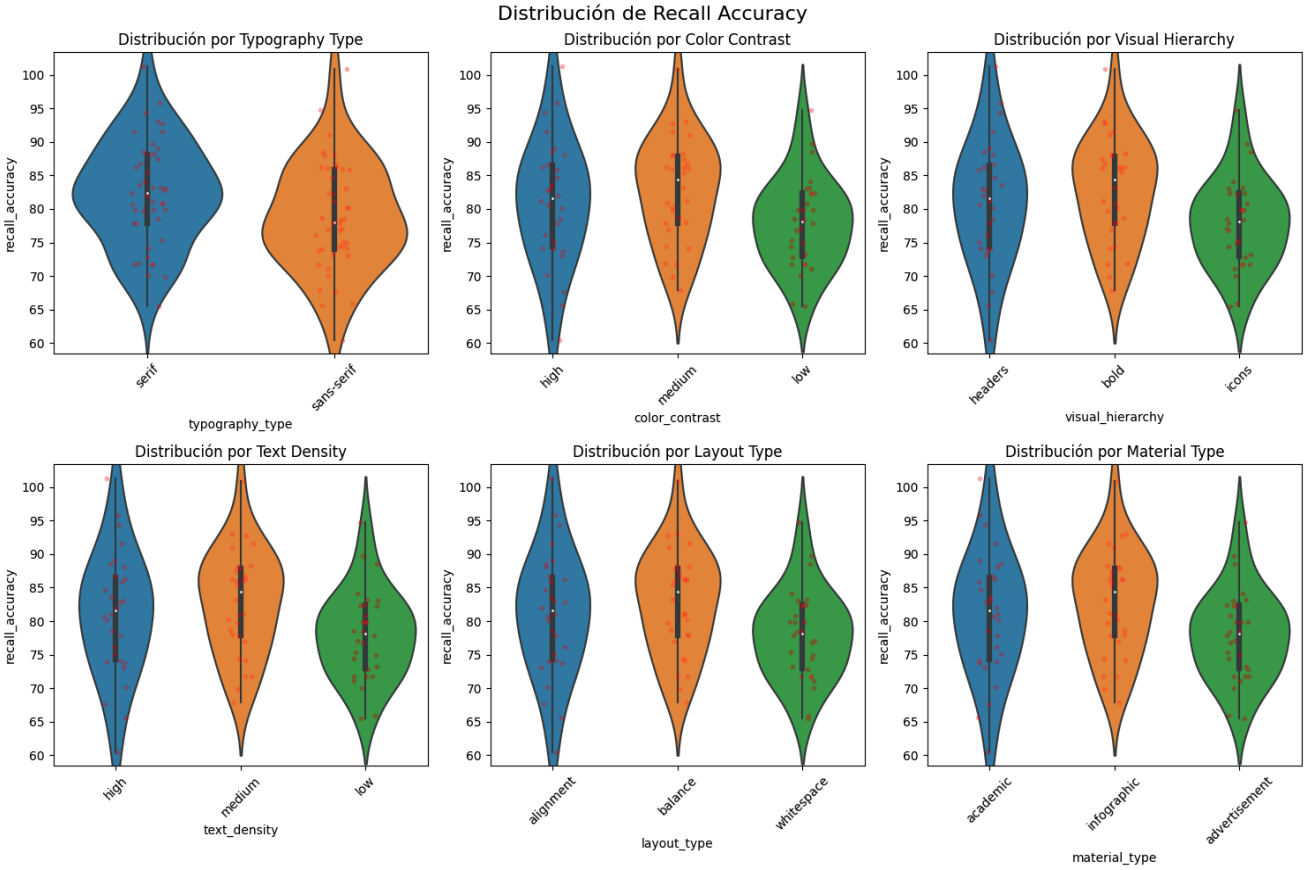

Figure 2. Distribution of information accuracy for data obtained

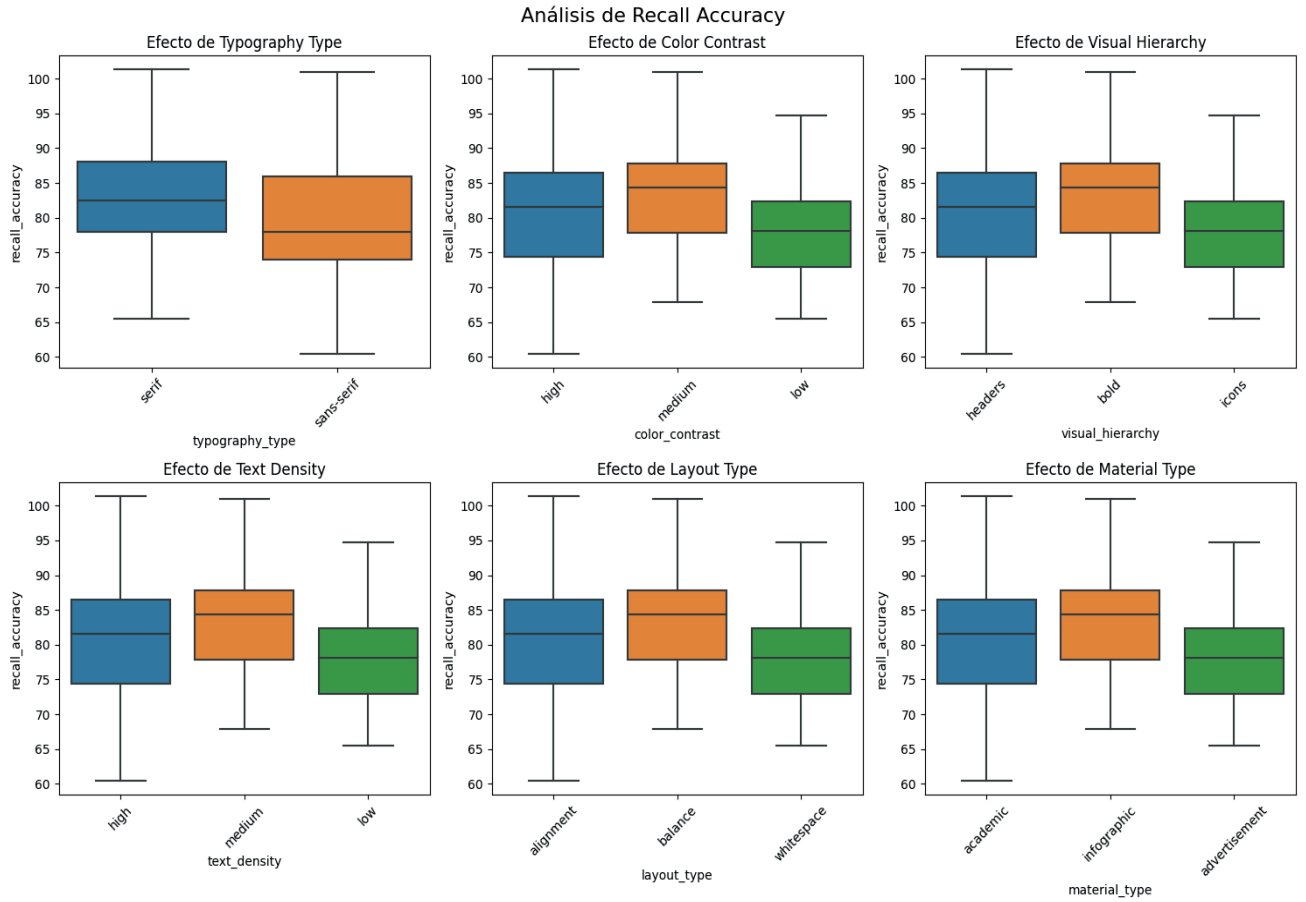

Figure 3. Analysis of information retention accuracy for data obtained

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To understand how graphic design shapes the ability to learn and remember, truly revealing patterns have been discovered. Researchers and designers are faced with a fundamental question: how can visual elements transform how we absorb and retain information?

The data presented in figure 1 reveals that readers in the first group grasped the information more quickly, with an impressive immediate retention rate of 69 %.

However, those who read the serif font showed deeper and more lasting comprehension, achieving 82 % accuracy in subsequent recall (figure 2). It is as if the serifs act as small bridges, connecting not only the letters but also the ideas in memory.

However, the most surprising finding came from the contrast study. Contrary to what many might expect, softer contrast proved more effective. Participants who worked with low-contrast materials showed superior retention, both immediately (70 %) and in the long term (65 %), with the results shown in figure 3.

These results show that the way information is visually organised also played a crucial role. Icons, those small symbols that are so widely used in the digital age, proved to be powerful allies of memory, facilitating immediate retention of 70 %. As shown in the correlation matrix presented in figure 4.

Figure 4. Correlation matrix between icon size and information retention

Space, that invisible but fundamental element, proved to be as important as the content itself. Materials with moderate information density and generous use of white space were more pleasant to read. They led to better long-term retention, as shown by the response times presented in figure 5.

Critical was how different presentation formats affected learning. Infographics emerged as the undisputed champions of recall accuracy, achieving 82,82 %, as shown in figure 6. Combining visual elements with concise information, this format speaks a language the brain understands naturally.

The results suggest that we need to be more flexible and mindful in our design decisions. For materials that require quick comprehension, such as news or emergency instructions, using sans-serif with soft contrast and abundant visual elements might be the best option. On the other hand, for content that seeks deep and lasting understanding, such as educational materials or technical documents, a combination of serif, medium contrast, and a clear hierarchical structure could be more effective, as a strong correlation was found between these and information retention (figure 7).

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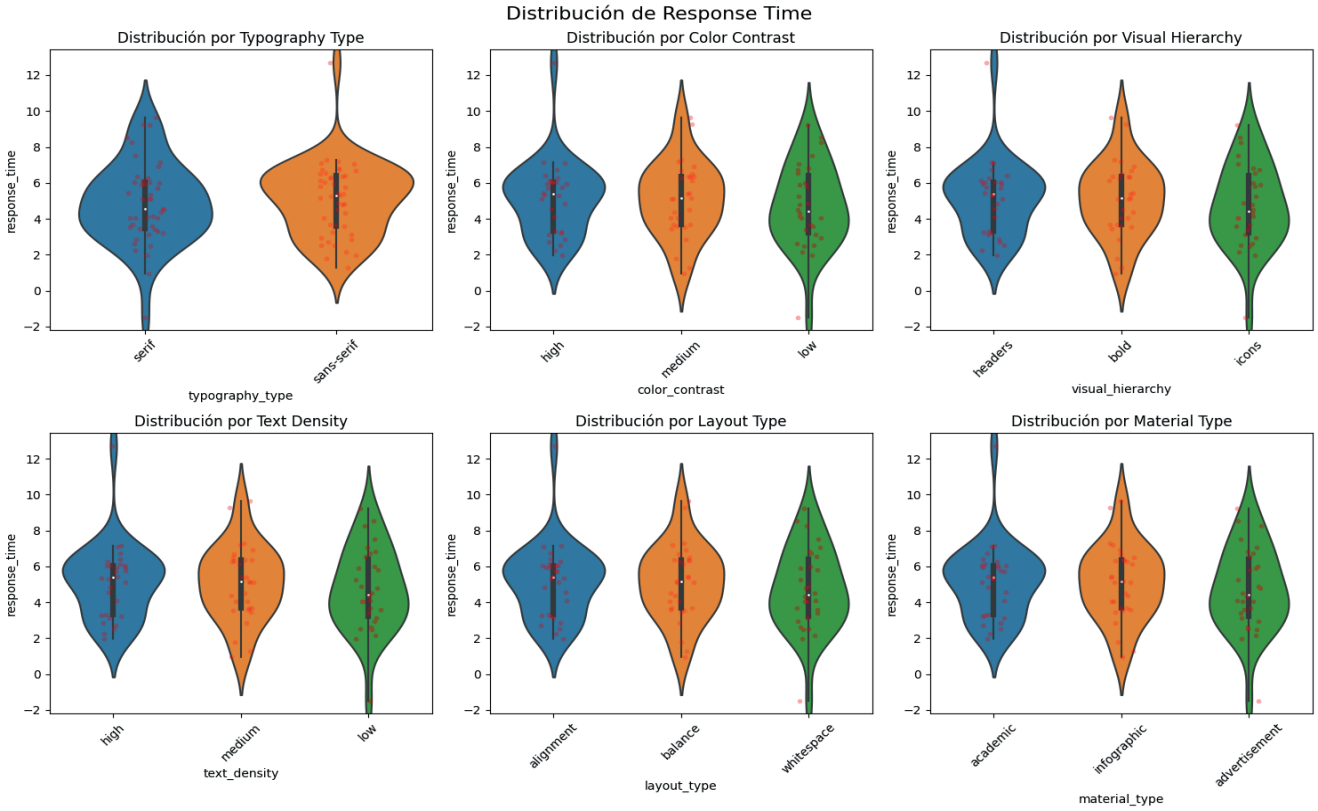

Figure 5. Response time distribution for data obtained

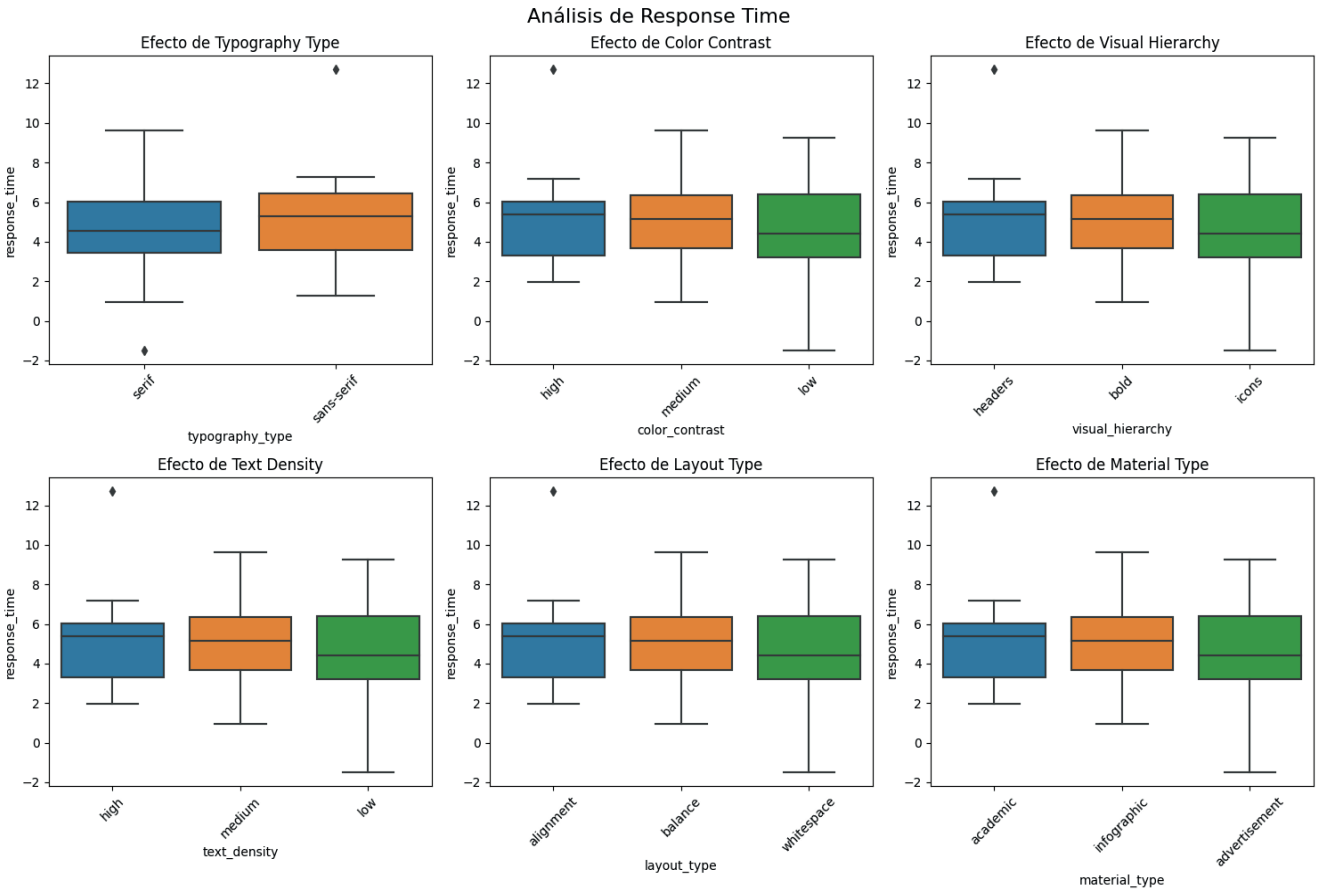

Figure 6. Response time analysis for data obtained

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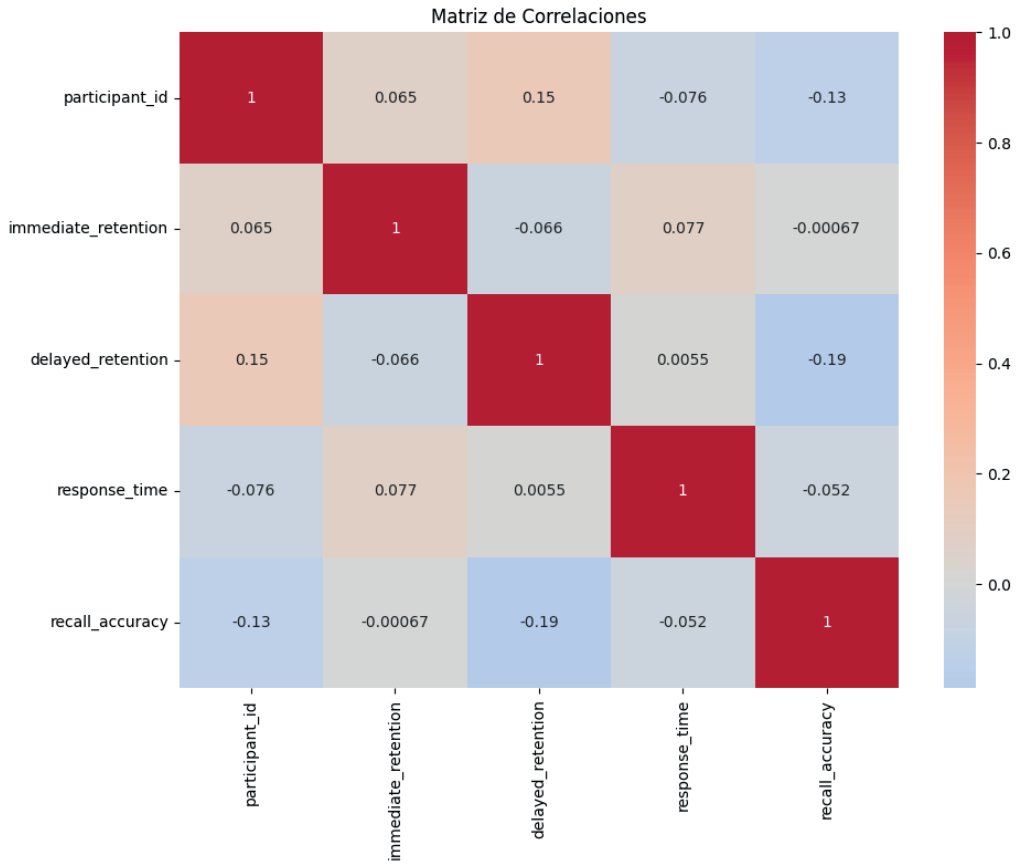

Figure 7. Correlation matrix between hierarchical structure of materials and information retention

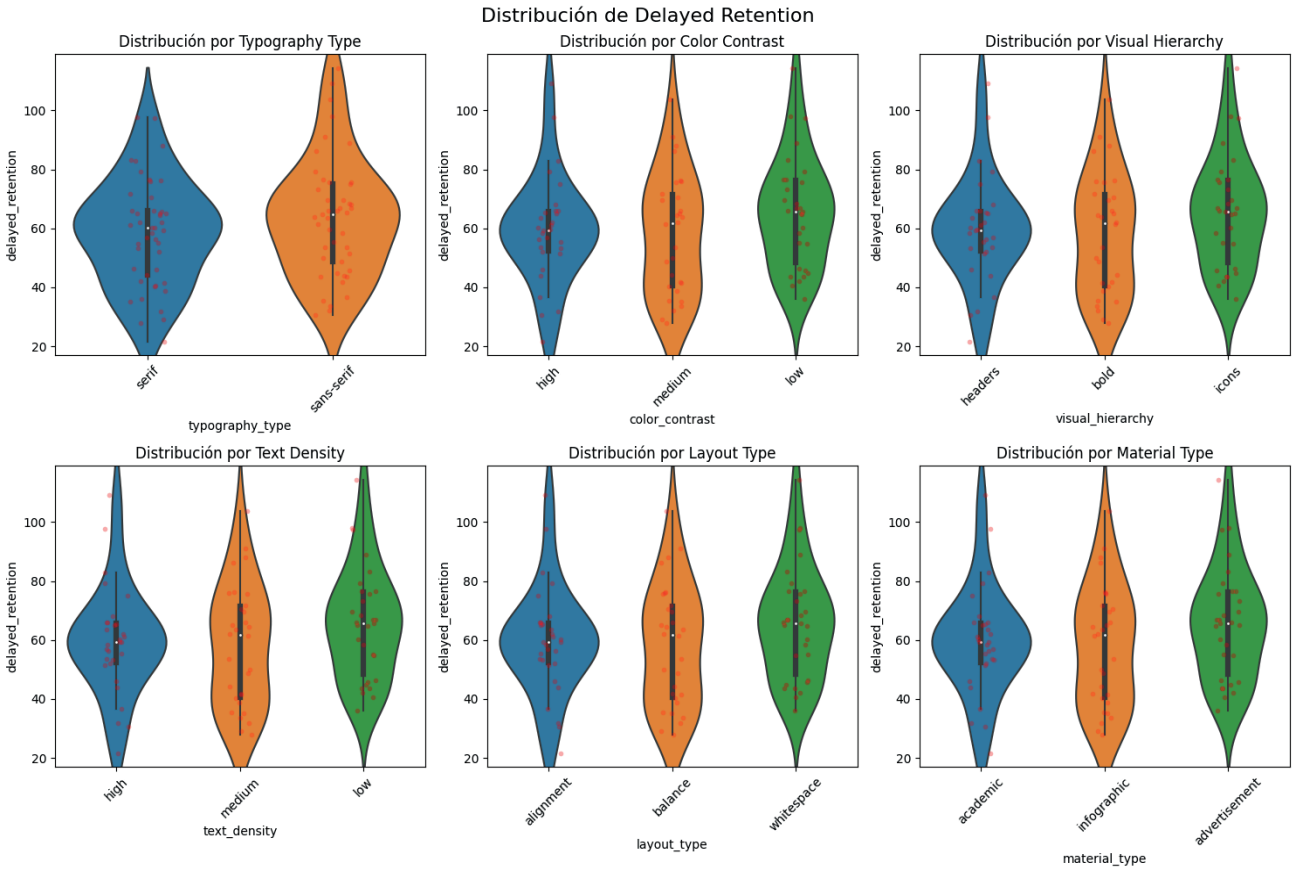

Figure 8. Distribution of delay in information retention

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The most striking aspect of these findings is that they confirm that design is not just a matter of aesthetics but a powerful tool for improving how information is learned and communicated. Every element, from the smallest serif to the largest white space, plays a role in the complex dance of learning and memory and prevents delays in information retention, as shown in figure 8.

Ultimately, these results invite us to rethink how learning design is carried out and remind us that every design decision is an opportunity to make information more accessible, memorable, and meaningful to audiences. Effective design is not just a matter of following trends or rigid rules but of deeply understanding how humans process and remember information, avoiding delays in retention, as shown in figure 9.

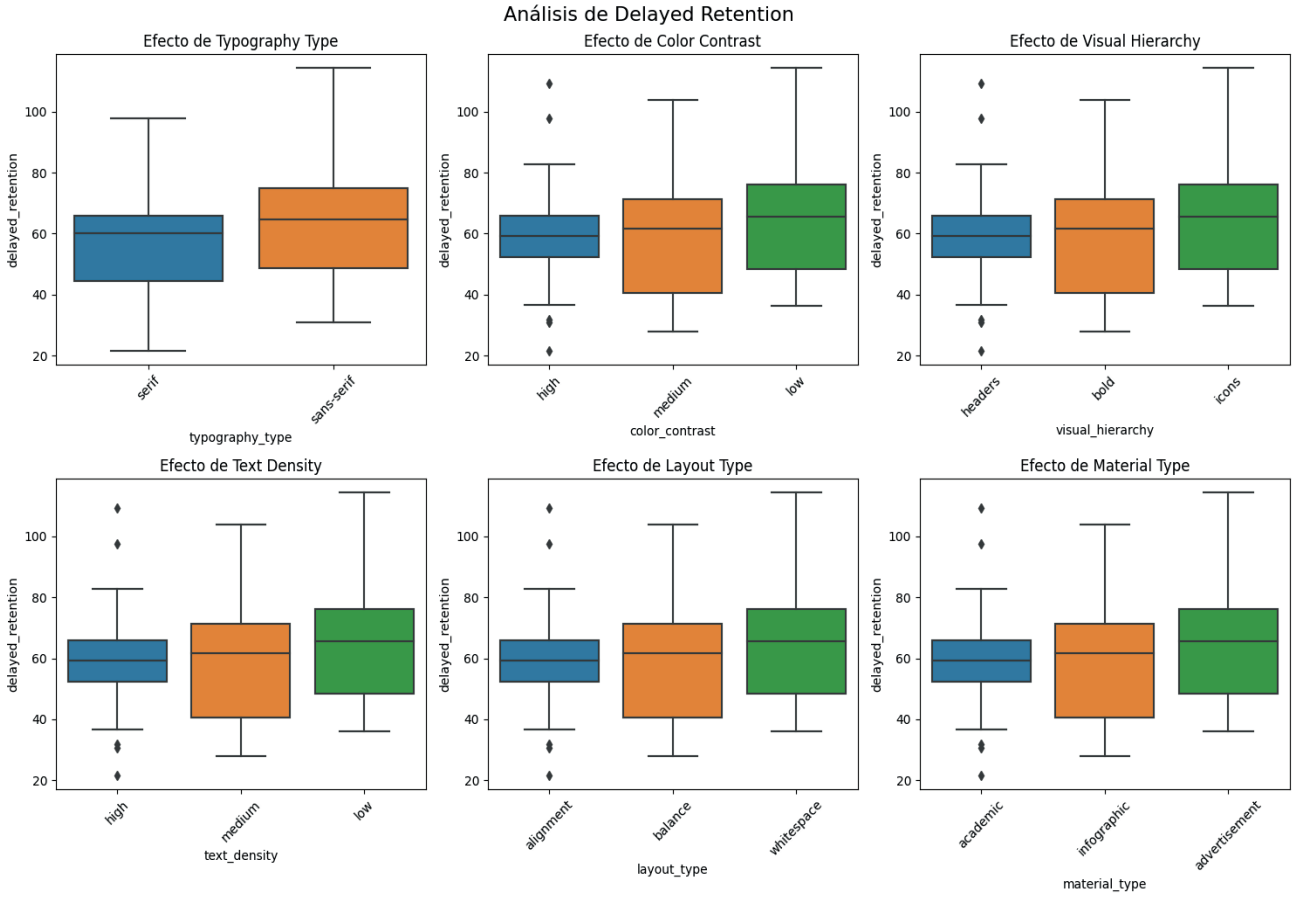

Figure 9. Analysis of delay in information retention

DISCUSSION

The influence of graphic design on learning and retaining information has been a topic of interest in recent decades, with various studies revealing that appropriate design can significantly enhance comprehension and memory of presented content. The results obtained in this study highlight how different aspects of graphic design, such as typography, contrast, use of icons, and space, can significantly influence learning effectiveness.[15,16]

First, the data showed that participants who read sans-serif typeface (with a modern, clean design) achieved 69 % immediate retention. This finding highlights the ability of sans-serif fonts to facilitate rapid reading, which could be particularly useful in situations where information needs to be assimilated quickly, such as in manuals or instructions.[17] However, participants who read in a serif typeface, which is more classic and decorative, showed deeper long-term comprehension, with a retention rate of 82 %. This result suggests that serifs help connect ideas more effectively, facilitating lasting comprehension of concepts, as observed in previous studies on memory retention in long texts.[18,19]

In terms of contrast, the results were surprising. Contrary to general intuition, participants who used materials with soft contrast showed higher immediate (70 %) and long-term (65 %) retention. This phenomenon can be explained by the fact that soft contrast provides a less stressful visual experience, allowing readers to process information more naturally and less forcefully.[20] Research suggests that too much contrast could overload cognitive mechanisms, making retention more difficult.[21]

In addition, the use of icons as visual elements to organize information also proved effective. Icons helped participants remember the content with an immediate retention rate of 70 %. This supports the idea that icons,

by acting as 'visual anchors,' facilitate encoding information into short-term memory, which aligns with studies highlighting the importance of visual elements in comprehension.[22,23]

The use of space, especially white space, also played a key role in learning effectiveness. Materials with moderate information density and sufficient white space were more pleasing to the eye and led to better long-term retention. This finding aligns with previous research demonstrating how white space can help readers process and store information more efficiently, avoiding cognitive overload.[24,25]

Finally, the presentation format also had a considerable impact on the results. Infographics, which combine images with concise information, stood out for their ability to improve recall accuracy, achieving 82,82 % retention. This finding supports the idea that infographics not only enhance the accessibility of information but also facilitate understanding and memorization, a topic widely discussed in the literature on graphic design and learning.[26]

CONCLUSIONS

The results suggest that effective graphic design for immediate retention should prioritize clean typography, soft contrasts, icons, low text density, layouts with ample white space, and more visually appealing presentation formats, such as those used in advertising. These elements facilitate more efficient cognitive processing and better information encoding in short-term memory.

The findings invite us to reconsider how graphic design can be a powerful tool for improving learning and information retention. Design should not only be seen as an aesthetic issue but as an integral strategy for optimizing how content is perceived and understood, thereby achieving better user understanding.

Visual elements such as typography, contrast, icons, and space should be carefully selected and adapted according to the type of content and educational objective. As we move towards a more visually oriented future, these design strategies may be crucial in making information more accessible and memorable.

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CONFLICT OF INTEREST

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