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ORIGINAL ARTICLE

Network-based analysis for identifying visual patterns in advertising

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ABSTRACT

Digital advertising played a pivotal role in shaping public perceptions of technology, with Instagram emerging as a predominant platform for visual brand communication. In this context, the analysis of visual patterns emerged as a strategic approach to comprehending the narratives that underpinned the positioning of technology companies. This article investigated visual patterns in the digital advertising of technology brands by constructing and analyzing similarity networks among images published on Instagram. A total of 4,580 images from four brands (three Brazilian and one multinational) were collected, and these were selected based on objective market presence and economic sector criteria. The images were transformed into embeddings using convolutional neural networks. A graph was then constructed and analyzed using the Gephi software, with the analysis based on vector similarity. Modularity and centrality metrics were applied to identify visual structures. The results of the analysis revealed the presence of cohesive clusters, each exhibiting a distinct graphic style. Among the brands analyzed, Positivo Tecnologia demonstrated a high degree of visual cohesion, characterized by the clear delineation of thematic groupings and a discernible strategic organization. Centrality metrics identified influential images within clusters, while modularity scores highlighted the fragmentation and centrality of visual concepts. The efficacy of the embedding-based and network analysis approach in mapping visual patterns in digital advertising was demonstrated, thereby revealing the aesthetic coherence and visual identity of technology brands. The adopted methodology delineated a replicable paradigm for prospective investigations into digital communication strategies, thereby contributing to advancements in the domains of communication design and computational image analysis.

Keywords: visual advertising; image embeddings; network analysis; Instagram; brand identity; communication design.

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1. INTRODUCTION

Digital advertising has played a pivotal role in shaping social imaginaries related to technology, particularly within the context of visual social media such as Instagram. These platforms have become pivotal to the communication between brands and consumers, thereby intensifying the strategic importance of visual analysis in understanding how the public perceives and engages with technology companies (Carpio-Jiménez *et al.,* 2024; Highfield & Leaver, 2023). In this scenario, images transcend their original aesthetic function and operate as vectors of identity, emotion, and strategic positioning (Manovich, 2020). The growing prevalence of visual content on social networks has been observed not only in commercial contexts but also in sociopolitical disputes, as demonstrated by Lemos *et al.* (2024). Through meticulous analysis of visual elements in social media (X [formerly Twitter]) posts related to the Israel-Palestine conflict, the authors unveil the deliberate mobilization of visual attributes to construct narratives, shape collective imagination, and intensify public emotional engagement. These findings underscore the importance of examining visual patterns as semiotic practices strategically employed, particularly in communication ecosystems characterized by noise and disinformation. Consequently, computational methodologies for interpreting visual content are imperative for comprehending the symbolic and performative logic of brand communication on digital platforms.

In the context of Brazil, a discernible shift has been observed in the communication strategies employed by technology brands. The shift entails a transition from a predominantly technical approach to a more emotional and human-centered perspective. According to Eickel (2024), this shift can be attributed to brands' efforts to align with the symbolic and affective expectations of contemporary society, where technical product features are subordinated to narrative construction. However, the utilization of a variety of visual approaches by different brands poses challenges in identifying aesthetic coherence and communicational effectiveness. In response, this study proposes the utilization of computational techniques that transform images into embeddings—that is, numerical vectors generated by convolutional neural networks. These embeddings facilitate the measurement of visual similarities and the construction of analytical graphs (Ng *et al.,* 2022; Zannettou *et al.,* 2020). This approach, consistent with the concept of metapictures proposed by Rogers (2021), facilitates both structural and interpretive interpretations of the visual culture prevalent on digital platforms. This article explores the emergence of visual patterns and organizational structures from Instagram advertising images of technology brands, utilizing a comprehensive analysis of visual similarity networks. The article presents an interdisciplinary theoretical framework, describes the applied methodology, and discusses the findings, concluding with reflections on the contributions of this approach to the field of communication design in digital advertising.

2. METHODOLOGY

The technical-theoretical context of this study is situated within the field of "communication design," with an emphasis on "graphic and information design" resources applied to digital environments, particularly in the context of advertising campaigns disseminated on social media. The study aims to understand how technology brands visually structure their messages through the analysis of images published on their official Instagram profiles. The methodology employed comprised four primary stages: (1) brand selection, (2) data collection and preparation, (3) image vectorization using neural networks, and (4) network analysis for the identification of visual patterns.

2.1. Brand selection

To ensure analytical consistency, objective criteria were defined for the selection of two Brazilian and two multinational brands operating in the technology sector, with a focus on the consumer electronics industry:

Criteria for multinational brands:

- Operate in the technology economic sector.
- Be active in the consumer electronics industry: commercialize physical products intended for professional and personal use.

- Be publicly traded on one of the world's major stock exchanges in 2024 (NYSE, Nasdaq, Euronext, or Shanghai Stock Exchange).
- Be the company with the highest market capitalization in the sector, according to data from the Stock Analysis platform.

According to the aforementioned criteria, Apple Inc. was selected as the multinational representative, given its preeminent status as the largest market-cap company in the technology and consumer electronics sector (US$3.43 trillion in 2024).

Criteria for Brazilian brands:

- Be founded in Brazil.
- Operate in the technology economic sector.
- Have national reach in the distribution of their products.
- Commercialize physical products intended for professional and personal use.
- Be listed in the Brazilian National Registry of Legal Entities (CNPJ) in 2023.
- Be publicly traded on B3 (the Brazilian Stock Exchange) in the information technology sector.
- Be among the top three companies ranked in the "computers and equipment" segment.

Based on these conditions, the Brazilian brands selected were Intelbras, Multilaser, and Positivo Tecnologia, according to B3's classification in the "information technology" sector.

2.2. Data collection and preparation

The dataset under consideration contained a total of 4,580 images, which were collected automatically on November 14, 2024, using the software 4k Stogram. This software enables full extraction of posts from public Instagram® profiles. The collection encompassed all available feed content from the selected brands, from the inception of their accounts' activity until the cutoff date, ensuring historical and volumetric representativeness.

2.3. Processing and vectorization

The images were processed in the Google Colab® environment using libraries such as TensorFlow and Keras. In the context of visual embedding extraction, the MobileNetV2 model (Sandler *et al.,* 2018) was selected for its implementation, with the model having been pretrained on the ImageNet dataset (Deng *et al.,* 2009). The final classification layer was removed, and global pooling was applied (pooling = "avg"). This model is distinguished by its optimal balance between computational efficiency and generalization capacity in visual tasks. Each image was resized to 224×224 pixels and preprocessed according to MobileNetV2 specifications. Subsequently, it underwent a transformation into a 1,280-dimensional feature vector (embedding), thereby encapsulating visual attributes such as color, texture, shape, and spatial composition. The similarity between the embeddings was measured using the cosine distance, a metric suited to quantifying angular proximity between vectors in high-dimensional spaces. This metric is particularly effective for evaluating visual similarities independent of scale. Subsequently, a similarity matrix was formulated for all image pairs based on these values. A graph was constructed from the aforementioned matrix employing the NetworkX library, thereby establishing connections between image pairs exhibiting similarity above a predefined threshold. The nodes of the graph are represented by images, and the edges represent connections to visual similarity. The final graph was exported in ".graphml" format and subsequently analyzed in Gephi, a software program that facilitates the identification of visual clusters and the calculation of centrality and modularity metrics.

2.4. Network analysis and visualization

Network analysis was conducted using Gephi® software, which enables the visualization and exploration of large-scale graphs. The ForceAtlas2 algorithm was implemented to optimize the spatial organization of nodes (images), thereby enhancing the visibility of similarity-based groupings. The calculation of modularity facilitated the identification of cohesive visual clusters, while centrality metrics (degree, closeness, and betweenness) highlighted the most influential, representative, or intermediary images within each cluster. To support the qualitative analysis of the clusters, Python® and

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ChatGPT® were utilized to map the image files corresponding to each identified cluster. The integration of graphical reading and network structure fostered comprehension of the aesthetic and strategic organization of the posts, thereby unveiling the visual communication patterns of the brands.

3. RESULTS

The results of the study indicated the formation of distinct clusters, suggesting the presence of varied visual approaches to the representation of technology. Centrality metrics have been shown to identify influential nodes, which are associated with recurring or central visual elements in advertising campaigns. The application of modularity revealed cohesive communities represented in the graph (Figure 1), while the visual analysis of the clusters (Figures 2 and 3) highlighted a diversity of graphic styles.

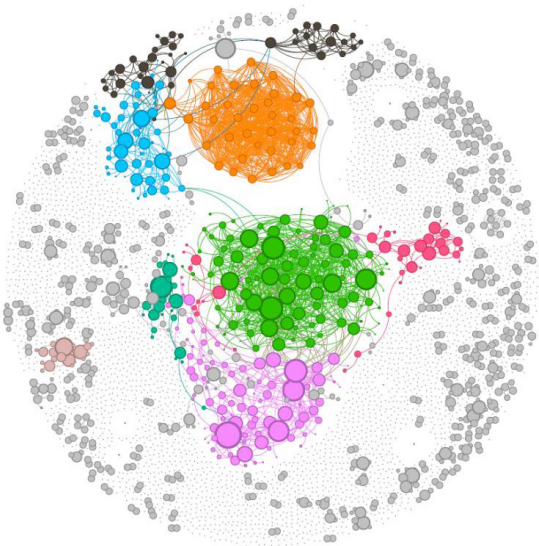

Figure 1. Graph of the visual structure of the advertising image dataset. **Note.** Prepared by the authors.

Figure 2 presents the Gephi® interface, which illustrates the classification of visual communities generated by the modularity algorithm. Each color in the visual similarity network represents a distinct cluster identified within the set of images. The numbers on the left refer to the internal code assigned to each modularity class, while the values in parentheses indicate the relative proportion of each cluster in relation to the total number of nodes in the network. A close examination reveals that the most prominent clusters are those designated as 233 (2.03%), 176 (1.97%), 228 (1.62%), and 462 (0.85%), suggesting that these communities aggregate the most significant number of visually analogous images. The distribution of network elements reveals a progressive concentration, in which a few clusters account for a significant portion of the network, while most others display relative frequencies below 0.5%. This pattern suggests that specific visual strategies and narrative structures were utilized repeatedly, leading to the aggregation of analogous content. The concentration of images within specific clusters may reflect stronger aesthetic consistency, repetition of layouts, or similar thematic choices —elements that reinforce the visual identity of the brand analyzed, which was predominantly "Positivo Tecnologia," as identified in previous stages of the study.

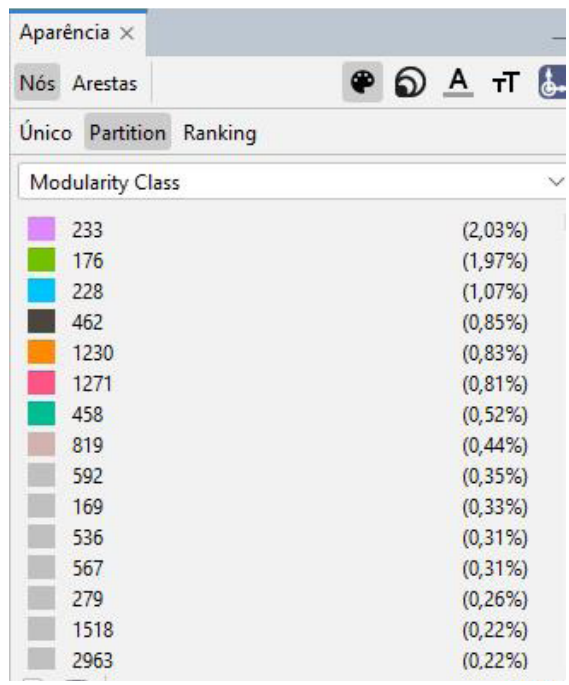

Figure 2. Modularity classes and relative frequency of visual clusters in the similarity network (Gephi interface). **Note.** Prepared by the authors.

The analysis of Cluster 01 identified the most connected, accessible, and representative images within the group. Degree centrality highlighted images such as "2024-02-05 17.30.07 3296261446572018958_44278906202.jpg"

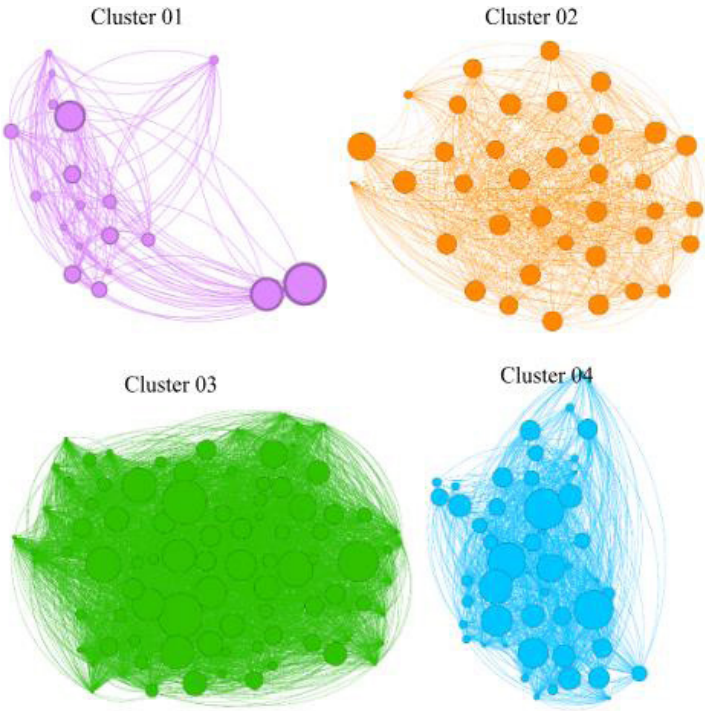

Figure 3. Clusters extracted from the image dataset. **Note.** Prepared by the authors.

Figure 4. Example of the most connected and representative images in Cluster 01.
Note. Official Instagram account of the brand (Positivo Tecnologia, 2023).

(Figure 4A) and "2024-05-01 10.00.56 335836 6039422936045_44278906202.jpg" (Figure 4B), both with a degree of 1.0, indicating that they are connected to all other relevant images in the cluster. Closeness centrality was also maximal (1.0) for these same images, suggesting that they visually synthesize the content of the cluster in a direct way. The betweenness centrality, with a value of 0.0061, indicated that these images play a moderate role in connecting different visual subgroups. The subsequent analysis of edge weight distribution yielded an average similarity value of 0.6180, with variations ranging from 0.5008 to 0.7508. These values indicate significant visual cohesion, with a standard deviation of 0.0592, reflecting subtle variations in similarity among the images.

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In Cluster 02, the most connected and representative images were identified as "2024-05-08 17.30.10 3363665610879393167_44278906202.jpg" (Figure 5A) and "2021-04-07 18.30.08 2546873537343003210_44278906202.jpg" (Figure 5B), both with a degree and closeness centrality of 1.0. These metrics serve to reinforce the notion that the images are at the core of the cluster, and they visually synthesize its primary characteristics. The betweenness centrality, which assumes a minimal value of 2.7e−05, indicated that these images exerted negligible influence as mediators between different visual subgroups. The distribution of edge weights indicated an average similarity of 0.6500, with values ranging from 0.5001 to 0.9050 and a standard deviation of 0.0535. This finding suggests the presence of a cohesive cluster with some stronger connections.

Figure 5. Example of the most connected and representative images in Cluster 02.
Note. Official Instagram account of the brand (Positivo Tecnologia, 2023).

The analysis of Cluster 03 identified "2024-07-01 17.29.17 3402803057722220810_6233 4512939.jpg" (Figure 6) as the most connected image, with degree and closeness centrality equal to 1.0, suggesting that it visually represents the predominant content of the group. Other images, such as "2024-03-08 17.30.10 3319454288079895385_44278906202.jpg," exhibited marginally diminished metrics, with a degree of 0.979 and closeness of 0.980. The betweenness centrality values were found to be low, with the file named "2024-07-01 17.29.17… jpg" exhibiting a value of 0.0091. This finding suggests that the file plays a moderate role in connecting subgroups. The subsequent analysis of edge weight distribution yielded an average similarity of 0.6195, with values ranging from 0.5000 to 0.9317. The standard deviation of 0.0737 indicated greater variation in visual cohesion for this cluster compared to the previous ones.

Cluster 04 exhibited images with high connectivity and accessibility, such as "2021-03-31 18.41.00254180559219834435 0_44278906202.jpg" (Figure 7A) and "2024-01-2218.04.05 3286131684432089082_4427890 6202.jpg" (Figure 7B), both with degree and closeness centrality equal to 1.0, distinguishing them as central representations within the group. The betweenness centrality metric exhibited consistent values of 0.00035, suggesting a low degree of influence as mediators. This finding is consistent with the observed reinforcement of the cluster's visual uniformity. The distribution of edge weights indicated an average similarity of 0.7909, ranging from 0.5001 to 0.9750, with a standard deviation of 0.1082. This finding suggests a high degree of visual cohesion within the cluster, although it exhibits greater diversity compared to the other clusters.

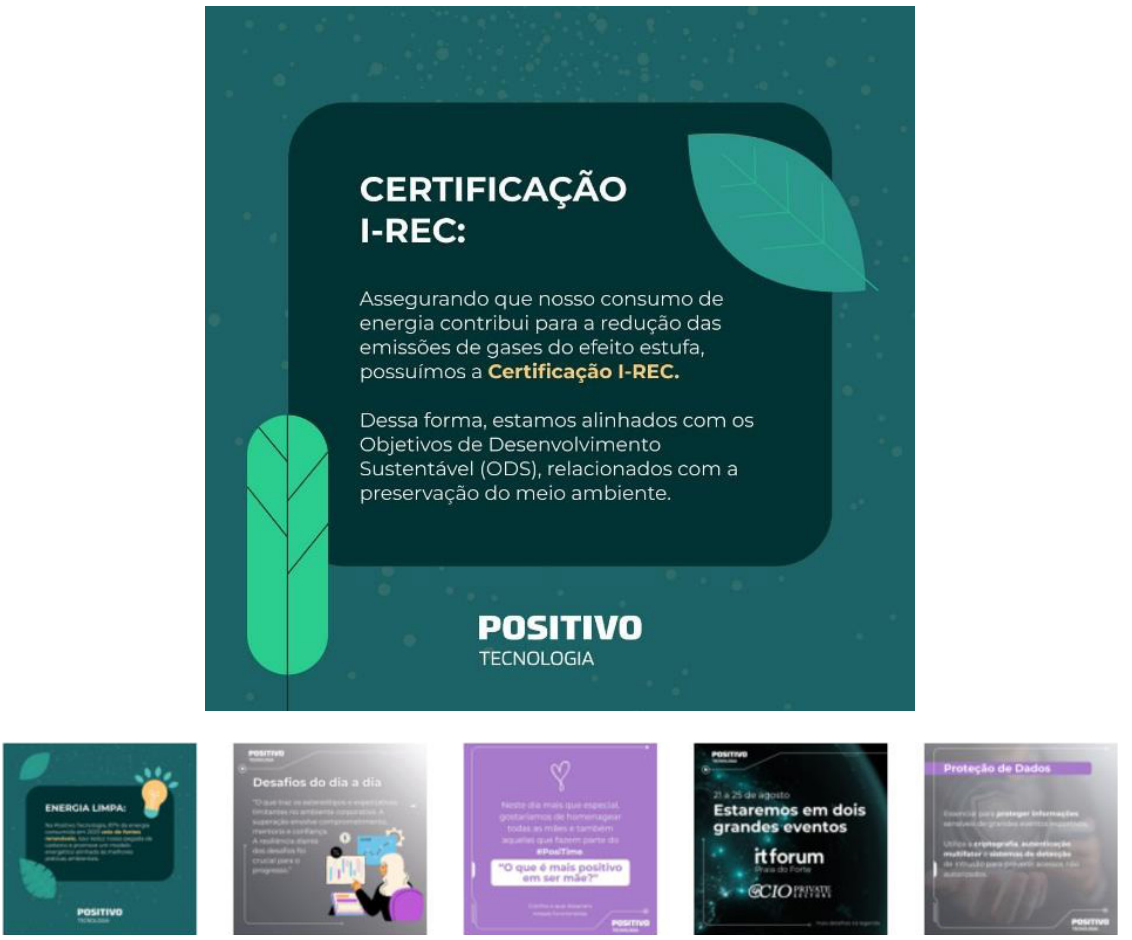

Figure 6. Example of the most connected and representative images in Cluster 03.
Note. Official Instagram account of the brand (Positivo Tecnologia, 2023).

Figure 7. Example of the most connected and representative images in Cluster 04.
Note. Official Instagram account of the brand (Positivo Tecnologia, 2023).

4. DISCUSSION

The subsequent analysis of the clusters yielded discernible patterns of visual organization and communication strategies employed by the brand under scrutiny, particularly "Positivo Tecnologia," whose content predominated among the top-ranked modularity clusters (Figure 2). This finding indicates not only a higher volume of publications but also a more cohesive aesthetic and thematic consistency compared to other brands. Cluster 01, which is centered on corporate and institutional events, serves to reinforce the dimension of "institutional visibility." This is achieved by anchoring said visibility in partnerships and business-oriented environments. Cluster 02 presents a narrative axis that prioritizes "human protagonism," incorporating employee testimonials and direct engagement, thereby aligning the brand with more affective and relational communication. The thematic scope of Cluster 03 is expanded through the incorporation of elements pertaining to "sustainability and innovation," which are frequently associated with the global agenda of the sustainable development goals (SDGs). Finally, Cluster 04 is characterized by the presence of "promotional and celebratory content," with a focus on awards, recognitions, and technological achievements that contribute to the brand's competitive positioning. These findings directly address the central research question: How do technology brands visually structure their messages in digital environments? The findings suggest that while visual strategies exhibit variability in intent, there is a discernible intentionality in the formation of thematic clusters characterized by recurring elements of color, composition, and visual narrative, which serve to reinforce aesthetic coherence.

The findings of this study are in alignment with those of related research, including those by Manovich (2020) and Rogers (2021), who have previously emphasized the role of visual patterns in comprehending digital culture. The identification of cohesive and thematically consistent clusters serves to reinforce the hypothesis that graphic design in digital communication transcends mere aesthetics, instead fulfilling structural functions in the organization of the symbolic dimension of brand messages and the performance of visual identity. From a pragmatic standpoint, the findings underscore the efficacy of computational instruments in mapping and appraising brand visual stratagems on an extensive scale. The application of embeddings and network analysis provides professionals in design, communication, and marketing with actionable insights. These insights facilitate the development of more consistent visual identities and the identification of the most influential content within a broad set of publications. This convergent structure can also be interpreted in light of studies such as Lemos *et al.* (2024), who demonstrate, within a different analytical context, how repetition and convergence of visual elements function as mechanisms of discursive sedimentation and narrative reinforcement. The recurrence of visual patterns can thus be understood as a deliberate communicative practice aimed at building a recognizable brand identity aligned with specific causes or symbolic values. In this sense, embedding-based network analysis proves to be valuable not only for morphological description but also as a diagnostic tool for assessing discursive visual coherence in digital communication strategies.

Theoretically, this study contributes to the intersection of communication design, network analysis, and digital culture, offering a replicable approach to the qualitative-quantitative analysis of visual content. Moreover, the implementation of neural networks and topological metrics unveils symbolic dynamics that may not be readily discernible through conventional visual analysis methodologies. However, it is imperative to acknowledge the limitations of this study. This study focused exclusively on static images published on Instagram feeds, excluding videos, carousels, and stories, which also play a significant role in the platform's visual ecosystem. Furthermore, while the sample size was considerable, it was constrained to four technology brands. This may limit the generalizability of the findings to other industries or cultural contexts. The approach based on visual similarity has also been demonstrated to fall short in capturing deeper semantic dimensions, such as symbolism or discourse. This limitation necessitates the employment of complementary methods, including semiotic analysis and qualitative interviews. Notwithstanding,

the findings offer pertinent insights into the manner in which brands establish visual coherence in digital environments, thereby contributing to the advancement of research in the domains of branding, design, and social media platforms.

5. CONCLUSION

This study demonstrated that network analysis is an effective approach for investigating visual patterns in advertising, thereby confirming the practical applicability of the method proposed by Ng *et al.* (2022) and Zannettou *et al.* (2020). These researchers employed neural embeddings and similarity networks to reveal thematic structures in coordinated operations. The findings further corroborated the conceptual framework of metapictures, as proposed by Rogers (2021), thereby reinforcing the potential of cluster-based graphical analysis as a critical tool for interpreting visual advertising strategies grounded in graphic coherence. The employment of visual embeddings in constructing the similarity graph, in conjunction with modularity metrics, proved to be instrumental in the identification of clusters and the revelation of internal structural dynamics. The modularity-based analysis indicated that the four primary clusters identified in the network comprised exclusively images from Positivo Tecnologia, despite the dataset encompassing content from four distinct technology brands. This finding suggests that Positivo Tecnologia's images exhibit greater interconnectedness, demonstrating higher levels of narrative and visual cohesion. This phenomenon may be indicative of a more consistent or distinctive communication strategy employed by Positivo Tecnologia. The identified clusters are indicative of well-defined thematic subgroups, suggesting strategic segmentation by the brand across institutional, human, environmental, and promotional dimensions.

The methodology employed in this article evinces considerable promise for replication in studies focused on branding, digital reputation, and identity coherence in visual media. Subsequent research endeavors may involve direct comparisons among the brands in the dataset to ascertain whether differences in modularity are influenced by factors such as posting frequency, visual quality, or structural properties of the visual communication network. Furthermore, additional studies are recommended to investigate the impact of these visual characteristics on audience engagement and brand perception, thereby expanding the implications of visual coherence in strategic communication.

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Conflict of interest

The author declares no conflict of interest related to the development and publication of this research.

Contribution statement

Conceptualization: Bianca Ariela Eickel Barel.
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Formal analysis: Bianca Ariela Eickel Barel.
Visualization: Bianca Ariela Eickel Barel.
Writing-original draft: Bianca Ariela Eickel Barel.
Writing-review & editing: Bianca Ariela Eickel Barel and Alexandre Leopoldo Gonçalves
Supervision: Julio Monteiro Teixeira (advisor).
Co-supervision: Alexandre Leopoldo Gonçalves, Rita de Cássia Romeiro Paulino, and Marcio Vieira de Souza (co-advisor).

Statement of data consent

The datasets and analytical materials (image sets, graph files, and source code) generated and analyzed during this study are available from the author upon reasonable request. ●

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