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Dynamic & Static Visual Representations as Multimodal Communicative Forms: A Social Semiotic Analysis of Scientific Visualization

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Abstract

Visual media increasingly shape scientific communication; yet, the semiotic distinctions between dynamic and static representations are inadequately understood in communication studies. This study, rooted in social semiotics and multimodal discourse theory (Kress & van Leeuwen, 2006; Jewitt, 2009), analyzes animations and static visuals as separate multimodal communicative forms, whose semiotic, temporal and modal structures affect meaning-making, conceptual integration and memory retention. The study employed a mixed empirical design with 120 participants, revealing that dynamic images promote conceptual integration via temporal cohesiveness, whilst static visuals improve memory through representational stability and diminished semiotic load. The Dynamic-Static Multimodal Communication Model (DSMCM) is introduced to elucidate how temporality, modality and semiotic density collaboratively shape viewer interpretation. The results enhance communication scholarship by showing that the effectiveness of visual representations stems not from technological complexity, but from multimodal design choices that influence interpretative engagement.

Introduction

Visual communication is becoming increasingly crucial in science communication, data journalism, documentary media and explanatory internet platforms. Animated and static visuals are

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commonly employed to elucidate abstract or imperceptible scientific concepts for general audiences. However, in communication study, these representational forms have rarely been examined through their semiotic structure. Social semiotics perceives communication as intentional design influenced by culturally ingrained selections of semiotic resources (Kress, 2010). From this viewpoint, animated and static graphics embody different modes of communication: animations convey meaning through movement and temporal progression, while static sights establish meaning through spatial arrangement and prominence. This study examines how these representational disparities influence meaning-making, positioning scientific visualization as a communicative technique rather than solely an educational one.

Objectives

The fundamental aim of this study is to analyze the functioning of dynamic and static scientific images as unique multimodal communicative forms within a social semiotic framework. The study aims to investigate how variations in semiotic density, modality and temporal structure influence viewers' processes of meaning-making in the interpretation of scientific concepts. Another purpose is to assess how these multimodal structures affect two communicative outcomes-conceptual integration and retention-thus defining the communicative affordances distinctively provided by dynamic and static representations. The study seeks to propose a conceptual model that theorizes the interplay of temporality, compositional stability and multimodal orchestration in influencing the communicative efficacy of scientific visuals within public communication contexts, including science journalism, explanatory media and documentary visualization.

Hypothesis

This study posits, grounded in multimodal discourse theory and social semiotics, that dynamic scientific visuals, characterized by elevated modality, temporal continuity and multimodal layering, will facilitate enhanced conceptual integration by allowing viewers to more coherently perceive causal relationships and processual sequences. It is additionally posited that static visuals, due to their representational stability, diminished semiotic density and slower

interpretive pacing, will enhance delayed recall by minimizing interpretive overload and enabling viewers to engage in prolonged, detail-focused examination. Collectively, these ideas suggest that dynamic and static visual forms will provide unique yet complementary communicative effects aligned with their semiotic structure.

Theoretical framework

The research is based on social semiotics and multimodal discourse theory, which define communication as the intentional selection and arrangement of semiotic resources to facilitate meaning-making within culturally specific contexts. This perspective acknowledges that animated and static visuals represent distinct semiotic technologies: animated visuals generate meaning through temporal vectors, shifts in motion-based salience and narrative sequencing, whereas static visuals depend on compositional balance, spatial hierarchy and representational accuracy. Utilizing Kress and van Leeuwen's grammar of visual design, the theoretical framework highlights three semiotic dimensions. Initially, representational meaning varies throughout modalities: animations emphasize processes and temporal causality, whereas static pictures highlight classification and relationship structure. Secondly, modality and semiotic density affect interpretative burden; dynamic forms enhance multimodal richness, whereas static forms diminish complexity and stabilize focus. Third, timing is regarded as a semiotic resource that influences narrative coherence and spectator interpretation. The principles contextualize the study's empirical results as communicative impacts stemming from multimodal design choices rather than solely cognitive or pedagogical processes, thus positioning scientific visualization within the realm of visual communication research.

Literature review

The multimodal communication theory posits that meaning arises from the interaction of several semiotic resources-such as imagery, movement, spatial configuration, color and typography-rather than solely from verbal structures (Jewitt, 2009; Bezemer & Kress, 2016). Kress and van Leeuwen's (2006) visual grammar delineates how representational, interactive and compositional meanings govern visual interpretation. These ideas are applicable to both static and dynamic visuals; however, animations enhance the semiotic repertoire

by incorporating temporality, narrative progression and dynamic vectors that express causal relationships (Kress, 2010). Bateman (2014) contends that dynamic media establish regular temporal grammars that direct viewer inference and generate narrative coherence.

Research on scientific visualization indicates that animations externalize transitions, rendering them perceptually accessible to viewers and diminishing the cognitive effort needed to mentally animate static material (Tversky, Morrison, & Betrancourt, 2002). Nevertheless, empirical studies indicate that animations may induce cognitive or semiotic overload due to their elevated modality requiring more swift interpretative integration (Hegarty, 2011; Lowe & Schnotz, 2014). Mayer's (2005) multimedia learning principles indicate that learners get advantages from dynamic representations that employ signaling, segmentation and spatial coherence, provided that the design is efficient. In contrast, static images offer representational efficiency and facilitate self-directed interpretation, frequently leading to enhanced long-term retention (Harp & Mayer, 1997; Schnotz & Rasch, 2005).

Media richness theory suggests that more complex communication modes enhance understanding in uncertain environments (Daft & Lengel, 1986), but diffusion studies emphasize the influence of representational technologies on social perceptions (Rogers, 2003). Recent research highlights the significance of multimodal design in public science communication, demonstrating that visual rhetoric, infographics and animated explainers affect audience trust, engagement and conceptual comprehension (McInnes & Hornmoen, 2018; Luzón, 2019). Research in data journalism contends that representational decisions influence audience perceptions of risk, uncertainty and scientific authority (Anderson & Thorbjornsrud, 2014).

Notwithstanding the expanding corpus of research, direct empirical comparisons between animated and static scientific graphics, analyzed via the lens of multimodal discourse analysis, are infrequent. Most research emphasizes learning outcomes over interpretative processes. This study examines this gap by analyzing how viewers interpret these forms through multimodal and social semiotic frameworks.

Methodology

A quasi-experimental approach was conducted involving 120 participants aged 14 to 16. The dynamic-visual group observed animated sequences depicting scientific procedures, whereas the static-visual group examined compositional frames directly extracted from those sequences. Participants engaged in conceptual interpretation tests, recall assessments and open-ended qualitative inquiries. Quantitative data assessed interpretation accuracy and recall, whilst qualitative comments underwent multimodal-coded thematic analysis. Ethical protections were maintained, encompassing informed consent, confidentiality and voluntary involvement. The school setting is characterized not as an instructional environment but as a micro-communication ecosystem where individuals encounter multimodal messages and participate in interpretive activities.

Data collection and analysis

Data were gathered via a quasi-experimental method including 120 people aged 14 to 16, who willingly engaged with informed consent and measures for anonymity ensured. Participants were randomly allocated to either a dynamic-visual condition or a static-visual condition. The dynamic group observed a sequence of scientific animations depicting processes like molecular mobility and energy flow, whereas the static group examined high-quality compositional frames derived from these animations. Both groups executed similar conceptual interpretation tests evaluating their capacity to express causal links, delineate representational systems and identify important elements. A postponed recall assessment evaluated retention. Open-ended narrative replies documented participants' interpretations of representational forms, yielding qualitative data for multimodal discourse analysis. The setting is regarded as a communicative context where participants interact with multimodal messages, rather than as a pedagogical intervention.

Quantitative data were analyzed using independent-samples t-tests to ascertain variations in conceptual interpretation and recall. Effect sizes were computed utilizing Cohen's d. Qualitative analysis employed multimodal-coded thematic analysis, utilizing visual grammar categories such as salience, vector, modality, spatial arrangement and temporal patterning. Participant descriptions were categorized based on references to movement, intricacy, clarity, pace

and interpretative challenge. The integration of quantitative and qualitative findings enabled the results to be understood within the established social semiotic framework, reinforcing the communicative rather than cognitive focus of the investigation.

Result

Dynamic images yielded markedly elevated conceptual interpretation scores, indicating that temporal vectors and dynamic sequencing facilitated interpretive synthesis. Participants often characterized animations as "depicting the process occurring," affirming that time served as a crucial semiotic resource for inference. Several participants encountered challenges in monitoring swift changes, indicative of semiotic overload linked to high-modality texts. Static visuals produced enhanced delayed recall, substantiating the assertion that representational stability, restricted modal variability and compositional clarity facilitate memory consolidation. Descriptions from participants highlighted the lucidity and retrievability of static pictures, consistent with studies on representational economy. The results indicate that the communication capabilities of dynamic and static pictures vary systematically based on their multimodal structure.

Discussion

The results corroborate social semiotic claims that communicative outcomes stem from representational design rather than technology. Dynamic pictures serve as high-modality multimodal texts, where their temporal arrangement offers substantial meaning-making potential, but with heightened interpretive demands. Static visuals function as low-modality texts that decelerate interpretation, enabling viewers to analyze relational structures without time constraints. These results enhance communication theory by illustrating that scientific visualization forms a representational ecology where semiotic selections influence communicative results. The study's consequences pertain to science communication, data journalism, documentary media and digital communication design, where the congruence of semiotic design with communicative intent is essential. Dynamic graphics are most useful for explanatory journalists and visual designers where conceptual explanation is paramount, while static representations excel in circumstances requiring correctness, clarity and retention.

Conclusion

Dynamic and static scientific images constitute separate multimodal communication systems, with their semiotic frameworks influencing viewer interpretation in varied manners. Dynamic images improve conceptual integration by utilizing temporality and multimodal richness, whereas static visuals boost retention through representational stability and decreased semiotic density. The Dynamic-Static Multimodal Communication Model offers a theoretical framework for comprehending the impact of visual communication design on meaning-making in scientific and media contexts. This study contextualizes scientific visualization within communication scholarship and enhances a multimodal comprehension of how representational decisions shape public sense-making.

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