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## Reading Effectiveness of Information Graphics in Data Journalism: Evidence from Eye-tracking Postprint

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### Abstract

[Purpose/Significance] Using data journalism as the reading context and information graphics as experimental materials, this study employs eye-tracking and behavioral experiments and qualitative interview methods to investigate readers' reading effectiveness of information graphics, explore their cognitive and visual responses, and provide references for optimizing data journalism design strategies.

[Method/Process] A two-stage single-factor design experiment was adopted. Stage one was an eye-tracking experiment that examined subjects' average fixation count, fixation duration, and subjective satisfaction with different types of data journalism information graphics. Stage two was a behavioral experiment on information graphics reading effectiveness, exploring the impact of different data presentation forms in information graphics on reading effectiveness, with subjects' reaction time and accuracy rate as dependent variables.

[Results/Conclusion] Data journalism reading exhibits a “Z”-shaped visual trajectory; the lead paragraph is a key browsing area; column headings receive high attention. The study also confirms that bar charts are more effective at attracting readers' visual attention, creating a holistic impression, and enabling readers to more actively engage in information processing; line charts have a slightly weaker ability to attract visual attention but highlight details effectively, resulting in the best memory performance; while pie charts consume the most cognitive resources in cognitive processing and should be used with caution.

## Full Text

### Preamble

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### Abstract

**[Purpose/Significance]** Using data news as the reading context and information charts as experimental materials, this study employs eye-tracking and behavioral experiments combined with qualitative interviews to investigate readers' reading effects on information charts, exploring their cognitive and visual responses to provide reference for optimizing data news design strategies.

**[Method/Process]** The experiment adopts a single-factor design in two phases. Phase one is an eye-tracking experiment examining subjects' average fixation count, fixation duration, and subjective satisfaction with different types of data news information charts. Phase two is a behavioral experiment on information chart reading effects, investigating how different data presentation forms in information charts influence reading outcomes, with response time and accuracy rate as dependent variables.

**[Result/Conclusion]** Data news reading follows a "Z-shaped" visual trajectory; the lead paragraph represents a key browsing area; and column titles receive high attention. The study confirms that bar charts more easily attract readers' visual attention, create holistic impressions, and encourage more active information processing. Line charts are slightly weaker in attracting visual attention but excel in highlighting details, yielding the best memory effects. Pie charts consume the most cognitive resources during processing and should be used cautiously.

## 1 Literature Review

### 1.1 Information Graphics in News Communication

Since 1988, researchers and journalists have explored data presentation in news texts, focusing on how to vividly display data to improve reading effects. These studies targeted "data in news," belonging to the field of precision journalism. Early research advocated using literary rhetorical techniques, employing comparison and metaphor to make numbers more accessible and comprehensible to readers. In 2010, Zhang Shufang discussed data charting in "Exploring Techniques for Processing Financial News Data," noting that using intuitive charts

to illustrate data can attract readers across different levels, making it easier for them to understand, remember, and recognize relationships and trends among quantities. This represented one of the earlier research papers addressing news visualization.

Research on data news visualization has proliferated alongside the development of “big data.” Current domestic scholarship on “data news” primarily focuses on the competency requirements big data poses for journalists, the transformation and challenges to news production workflows and editorial models, emphasizing topic selection, conceptualization, narrative techniques, and visualization methods, often reflecting on communication content and layout structure. Evaluations of data news reading effects, particularly information charts, predominantly rely on qualitative theoretical analysis lacking empirical and quantitative research support. Concurrently, international research on data news also concentrates on four main aspects: production processes, reporting content, data literacy, and ethics, with less attention to user reading experiences, presentation differences across media carriers, and reading effectiveness.

Information graphics (infographics) represent a method of visualizing numerical and textual information. Their functions primarily include presenting data, highlighting key points, diagramming processes, organizing sequences, revealing relationships, displaying situations, integrating content, expressing opinions, and providing analysis and interpretation. Data news information charts comprise two aspects: first, quantitative visualization, such as collecting, filtering, organizing, and analyzing abstract datasets and high-dimensional data to produce charts or diagrams that clearly present data and quantitative relationships to readers; second, textual visualization, such as condensing textual information through graphics or illustrations to help readers quickly capture key content. Currently, China’s data news design tends toward static charts, with numerous data news pieces remaining at the level of “understanding... in one picture.” While this reflects shortcomings in current data news production, it also demonstrates journalists’ reliance on information charts.

## 1.2 Visual Language and Design of Information Graphics

The theoretical foundation of information visualization primarily stems from French cartographer Jacques Bertin’s graphic theory proposed in 1967. Yale University statistics professor Edward Tufte subsequently published three representative works on information visualization in 1983, 1990, and 1997, laying the foundation for information chart design research. The key to information chart design lies in deconstructing and reconstructing visual language: Kostelnik and Roberts divide visual vocabulary potentially involved in design copy into four levels and three encoding methods, presenting “intrinsic, intermediate, extrinsic, and holistic” levels from micro to macro, with each level containing three encoding modes—text, space, and graphics—forming a 12-unit matrix that provides a framework for describing the visual language of specific copy.

Visual vocabulary in data news concentrates primarily on “extrinsic level design” (see Table 1 ), including images, data displays (such as bar charts, line charts, pie charts), diagrams, symbols, and data explanations. These elements, as independent entities, possess their own visual vocabulary and conventional forms, constituting the independent variables of this study.

Early domestic research on information graphics originated from education or information science fields. Since 2005, journalism and communication studies began focusing on visualization in American newspaper information graphics. In 2009, mainstream academic journals used Shenzhou spacecraft coverage from 1999-2008 as a case study to explore information graphics application in Chinese newspapers. In 2013, research on information graphics in journalism and communication surged: *Journalism* 界 published 12 consecutive papers on information graphics in 2013, elaborating on their application in political news, science and technology news, disaster reporting, financial news, and cultural features; analyzing three chart modes and discussing production methods such as data “crowdsourcing,” interactive design, community engagement, and relationships with social media. This series comprehensively summarized the application scope of information graphics in journalism and communication.

In terms of analyzing data news information charts from a design perspective, Zhang Jun argues that comprehensively integrating symbols, colors, images, and meaning can achieve artistic quality in news information chart design. Huang Juan proposes that on the basis of collecting and integrating data, better presentation and interpretation of news data can be achieved through contextual construction and graphic creativity. Huang Yajun, starting from visual thinking, points out that as an independent visual communication form for meaning representation, information charts should enhance text accessibility and improve reader cognition rates. Xinhua News Agency’s Gao Wei believes that layout design for information charts can employ three common formats—symmetrical balance, circular composition, and vertical composition—for narrative purposes based on themes.

### 1.3 Application of Eye-tracking Technology in Reading Effect Research

International eye-tracking research on reading dates back to the late 19th and early 20th centuries. In the early stages, psychology researchers noted basic eye movement characteristics during reading. With the rise of Western cognitive psychology in the mid-1950s, cognitive processes were understood as the brain’s processes of receiving, encoding, operating, extracting, and utilizing knowledge. Researchers such as P.A. Carpenter and M.A. Just, J.K. O’Regan, and G.W. McConkie and K. Rayner introduced eye-tracking analysis into psychological research, focusing on the relationship between eye movement processes and cognitive mechanisms.

Eye-tracking research currently applies to visual information processing mecha-

nisms, motivation and attitude studies, developmental psychology, educational psychology, and consumer psychology. In 1927, Shen Youqian, an early domestic eye-tracking researcher, conducted eye-tracking experiments on Chinese reading. Analysis of knowledge mapping in reading behavior eye-tracking research reveals that such studies primarily cover four knowledge clusters: basic reading issues, experimental content, experimental subjects, and technical models, with research frontiers involving patient-control comparisons, reading methods and materials, word processing and cognitive processes, and information processing and behavioral cognition. Common experimental paradigms in reading eye-tracking research include moving window, moving mask, boundary, rapid priming, disappearing text, and visual-situation paradigms. Researchers typically examine average fixation time, fixation count, and average saccade distance to reflect overall processing during reading; investigate single fixation duration, first fixation time, and gaze duration to reflect immediate processing in specific regions (such as target characters or words); and describe readers' visual information extraction processes through spatiotemporal eye movement characteristics.

In recent years, cognitive neuroscience research methods have been gradually adopted in journalism and communication. Through physiological measurement methods such as eye-tracking, EEG, and skin conductance, researchers can focus on readers' instantaneous decoding responses, "helping researchers extract relatively fixed associations between simple variables from complex communication processes layer by layer to reinterpret various aspects of communication phenomena." Eye-tracking research, in particular, reflects readers' visual movement patterns by recording eye movement trajectory characteristics, thereby revealing psychological activities and responses to visual element stimuli, and has been applied to understand consumer information acquisition behavior.

Since the late 1980s, the Poynter Institute, in collaboration with renowned visual design experts Mario Garcia and Pegie Stark Adam, and Gallup Applied Science in Princeton, conducted research on newspaper readers' reading behavior. This represented the newspaper industry's first use of eye-trackers for consumer behavior research and the earliest example of eye-tracking studies in journalism and communication. The research indicated that color pictures do not automatically attract readers' attention; content, size, and position are more important for capturing attention. In late 2003, the Poynter Institute, together with the Estlow Center for Journalism & New Media and Eyetools company, conducted the "EyeTrack III" study, which found that eye-catching headlines tend to attract netizens' attention more easily on pages, smaller fonts can lead to more focused reading, and short paragraphs attract twice as much attention as long paragraphs. The American Society of Newspaper Design used eye-trackers to discover that visual elements, not text, were most popular, with various newspaper elements ranked by reader interest as: graphic design, photographs, headlines, advertisements, digests, captions, and text.

In 2007, Renmin University of China's Communication Psychology Laboratory

first used eye-trackers to conduct experimental research on Chinese newspaper layout reading. The study found that the upper-left block became the “visual first landing point” for most readers, while the bottom-right block served as a “visual blind spot” for many. Most people exhibited a regular pattern of reading newspapers from top to bottom and left to right, with greater attention to large headline text than large images. These overall patterns of gaze flow provided intuitive and important guidance for newspaper layout design.

Comprehensive current eye-tracking research on news reading effects primarily focuses on textual materials, exploring visual range, perceptual span, fixation order, and attention competition models in text reading. Studies examining other reading materials such as pictures, diagrams, charts, and illustrations also analyze how images assist text reading, for instance, discussing frequency effects of interference stimuli in picture-word interference paradigms using fixation time and accuracy as indicators. In April 2018, Xu Xiangdong of Renmin University conducted eye-tracking tests and questionnaire surveys on data visualization communication effects, using a data news example to examine cognitive differences when readers read textual versus visual works, advancing eye-tracking experiments in data news research. This experiment focused on testing the overall communication advantages of data news from a holistic perspective. However, research using data news as the reading context and information charts as reading materials to explore readers’ attention levels and eye movement patterns remains scarce, and empirical research on their reading effects needs expansion.

## 2 Research Methods

### 2.1 Participants

In April 2016, the research team recruited 60 university students from China University of Geosciences (Wuhan) as subjects, including 30 males and 30 females, aged 18-28, from various majors, who had never participated in similar experiments. All were right-handed with uncorrected or corrected visual acuity of 1.0 or above, and no color blindness or weakness. Subjects participated voluntarily and received compensation upon completion.

### 2.2 Information Graphics as Independent Variables

Considering possible seasonal variations in data news, the sampling period covered an entire year. Xinhua Net’s current affairs data from January 2013 to December 2015 were selected, with the first seven articles from each month sampled, totaling 252 potential articles. Due to scheduling gaps, 170 actual current affairs data news pieces were sampled (including 100 text-based data news pieces with 565 image columns, and 70 numerical data news pieces with 190 image columns). Based on visualization object types, data news information charts were divided into two categories: those displaying textual content through graphic structures, termed text-based data news, classified according to logical relationships between texts; and those displaying quantitative rela-

tionships through graphic structures, termed numerical data news, classified according to logical relationships between quantities. A coding category table was created (see Table 2 ).

Content analysis revealed that parallel relationships were most common in text-based information charts, accounting for 60.18%, followed by total-part relationships at 11.33%. Although conceptual diagrams accounted for 10.62%, they were excluded from this study due to many unclear interfering factors, with remaining types showing dispersed proportions. Further analysis of data display types in parallel and total-part relationships identified three common parallel relationship diagrams: wind chime style, sticky note style, and text style (see Figure 1 [Figure 1: see original paper]), and three total-part relationship diagrams: bell style, peacock style, and turtle style (see Figure 2 [Figure 2: see original paper]).

Numerical information charts generally contain only ratio and interval relationships. Ratio relationships refer to continuous numerical relationships formed by measurement scales that allow addition, subtraction, multiplication, and division operations, such as percentages. Interval relationships refer to numerical relationships with fixed magnitude and order that measure category order intervals, allowing only addition and subtraction, not multiplication and division, such as counts or frequencies. Ratio and interval relationships share consistent data display types, includable as bar charts, line charts, pie charts, ring charts, radar charts, jadeite charts, maps, etc. Content analysis showed bar charts accounted for the largest proportion at 43.2%, followed by pie charts at 16.21%, and line charts at 13.7% (see Figures 3 and 4 [Figure 4: see original paper]).

Based on content analysis results, this study selected parallel relationships and total-part relationships from text-based data news, and ratio relationships and interval relationships from numerical data news—four chart categories with the largest proportions—as major research objects. Each major category was further divided into three subcategories, ultimately determining 12 chart types across four major categories as independent variable levels.

### 2.3 Experimental Design

The independent variable was the presentation form of information charts in data news. The dependent variables were eye-tracking indicators: average fixation count, total fixation duration, heat maps, subjective satisfaction ratings, and reading behavior response time and accuracy rate.

The experiment comprised two phases. Phase one was an eye-tracking experiment examining subjects' average fixation count, fixation duration, and subjective satisfaction with different types of data news information charts. As previous literature seldom indicates significant gender or age effects on information chart reading effects, this study used different presentation forms of parallel relationship, total-part relationship, ratio relationship, and interval relationship data news as independent variables in a single-factor experimental design, with

eye-tracking indicators and subjective satisfaction ratings as dependent variables. Phase two was a behavioral experiment on information chart reading effects, using a single-factor design to explore how different data presentation forms in information charts influence reading effects, with response time and accuracy rate as dependent variables.

## 2.4 Experimental Materials

Experimental materials were self-designed data news visual materials themed around current affairs news. Based on 12 information chart presentation forms—parallel relationship (wind chime style, sticky note style, text style), total-part relationship (bell style, peacock style, turtle style), ratio relationship (bar chart, line chart, pie chart), and interval relationship (bar chart, line chart, pie chart)—graphics were created using Windows blue for color coordination, with unified title positions and column structures (see Figures 1-4). To avoid familiarity effects with experimental materials, subjects rated data news information familiarity using a five-point Likert scale, with the lowest-scoring data news selected as experimental materials. Three themes were extracted from each of the four categories—parallel relationship, total-part relationship, ratio relationship, and interval relationship—creating 36 experimental materials (see Table 3), with experimental questions designed to measure memory effects for each material, totaling 36 questions.

## 2.5 Experimental Equipment and Procedure

The study used a Lenovo laptop connected to a Tobii iX2-60 eye-tracker and E-prime software. During the experiment, a quiet and comfortable environment was maintained, with subjects seated directly in front of the computer, eyes aligned with the screen center, and heads kept as still as possible. Head movement range was allowed to expand to 50 cm W × 36 cm H × 70 cm D in three-dimensional space, with eye-to-screen distance approximately 60-70 cm. Viewing angle was 27 degrees, with operating distance 45-90 cm. The experimenter adjusted the eye-tracker based on eye position to clearly capture subjects' eye movement characteristics.

First, the computer screen presented instructions, which the experimenter briefly explained. Subjects were instructed to browse news pictures according to their usual habits, with no time limit. After browsing one set of pictures, subjects entered the cognitive test interface, judging the “correctness” of presented questions and making keypress responses, automatically proceeding to the next question after answering. Following the judgment questions, subjects entered the satisfaction test interface for keypress responses, then browsed the second picture. The specific experimental process is shown in Figure 5 [Figure 5: see original paper]. After the experiment, qualitative interviews were conducted regarding information chart content and satisfaction.

After the experiment concluded, eye-tracking results from the Tobii X-60 were

exported as TXT format, imported into Microsoft Office Excel 2010 for categorization and organization, then formatted for SPSS processing and imported into SPSS 21.0 statistical software package. Invalid data caused by head mount movement, eye focus issues, or other physiological reasons were eliminated before data analysis.

### 3 Experimental Results and Analysis

#### 3.1 Eye-tracking Results for Data News Information Graphics

**3.1.1 Analysis of Eye-tracking Heat Maps** (1) **Data news reading exhibits a “Z-shaped” visual trajectory.** Overall heat map distribution still follows the top-to-bottom, left-to-right browsing sequence, showing a “Z-shaped” pattern on the layout. The upper-middle section of the layout is the main visual area, while the lower-right corner shows the fewest visual landing points, representing a visual blind spot (see Figures 6-9 [Figure 9: see original paper]).

(2) **The lead paragraph of data news is a key browsing area.** Heat maps show that in most experiments, subjects’ fixation duration on lead paragraphs was relatively long. From the perspective of fixation sequence, after quickly scanning headlines, readers generally proceeded directly to the lead paragraph (see Figures 6 [Figure 6: see original paper]-9 [Figure 9: see original paper]).

(3) **Column titles receive high attention.** Content analysis of Xinhua Net’s data news channel showed an average of 4-5 image columns per data news piece. Typically, each column is separated by column titles explaining each column’s theme. In experiments, subjects might not read every information point in images completely, but regardless of whether column titles were left-aligned or centered, they attracted subjects’ attention, demonstrating column titles’ attention-grabbing characteristics (see Figures 6-9).

**3.1.2 Average Fixation Count and Duration Results** One-way ANOVA was conducted on the four information chart categories, with results shown in Table 4 .

**Table 4 One-way ANOVA of Eye-tracking Indicators for Different Data News Types (N=60)**

Data News Type	Average Fixation Count	Fixation Duration
Parallel Relationship	2.742	1.867
Total-Part Relationship	4.789	2.814
Ratio Relationship	0.100	0.174
Interval Relationship	0.030*	1.652
	0.254	1.702
	0.200	0.615
	0.194	0.095

Data News Type	Average Fixation Count	Fixation Duration
	16.772	0.000***

Note: \* indicates  $p < 0.05$ , \*\* indicates  $p < 0.01$ , \*\*\* indicates  $p < 0.001$

The experiment showed no significant differences in average fixation count or duration between parallel relationship (wind chime style, sticky note style, text style) and total-part relationship (bell style, peacock style, turtle style) information charts. For ratio relationship (bar chart, pie chart, and line chart) information charts, significant differences existed in average fixation count ( $F=4.789$ ,  $p < 0.05$ ), but not in fixation duration ( $F=1.702$ ,  $p=0.194 > 0.05$ ). Post-hoc multiple comparisons indicated significant differences between bar charts and line charts, with bar charts receiving more fixations than line charts ( $p < 0.05$ ) (see Figure 10 [Figure 10: see original paper]).

One-way ANOVA for interval relationships showed no significant differences in average fixation count among the three chart types ( $F=2.814$ ,  $p=0.095 > 0.05$ ). However, fixation duration differences were highly significant ( $F=16.772$ ,  $p < 0.001$ ). Post-hoc multiple comparisons revealed that pie chart fixation duration was greater than bar charts; pie charts were greater than line charts; and bar charts were greater than line charts (see Figure 11 [Figure 11: see original paper]).

### 3.2 Subjective Satisfaction Results

To further examine subjects' subjective satisfaction with different data presentation forms in data news information charts, one-way ANOVA was conducted for each data news type (see Table 5). Results showed significant satisfaction differences in three types except parallel relationship.

**Table 5 One-way ANOVA of Subjective Satisfaction for Different News Types (N=60)**

News Type	Subjective Satisfaction
Parallel Relationship	0.209
Total-Part Relationship	4.925**
Ratio Relationship	5.714**
Interval Relationship	23.098***

Note: \* indicates  $p < 0.05$ , \*\* indicates  $p < 0.01$ , \*\*\* indicates  $p < 0.001$

In total-part relationship types, bell style satisfaction was significantly higher than peacock style ( $p < 0.01$ ), and turtle style satisfaction was significantly higher than peacock style ( $p < 0.05$ ).

For ratio and interval relationships, significant differences existed among bar charts, line charts, and pie charts ( $F=5.714$ ,  $p<0.05$ ;  $F=23.098$ ,  $p<0.001$ ). Post-hoc multiple comparisons showed (see Figure 12 [Figure 12: see original paper]): in ratio relationships, bar chart satisfaction was significantly higher than line charts ( $p<0.05$ ), and pie chart satisfaction was significantly higher than line charts ( $p<0.05$ ). In interval relationships, bar chart satisfaction was significantly higher than pie charts ( $p<0.001$ ) and line charts ( $p<0.05$ ), and line charts were significantly higher than pie charts ( $p<0.05$ ).

### 3.3 Cognitive Test Results

**3.3.1 Response Time Results** One-way ANOVA on response time for four data news information chart types revealed significant differences in response time across different data presentations for all four types (see Table 6 ). Post-hoc multiple comparisons found: in parallel relationships, text style response time was greater than sticky note style and wind chime style ( $p<0.05$ ); in total-part relationships, peacock style response time was significantly greater than bell style ( $p<0.001$ ), and turtle style was also significantly greater than bell style ( $p<0.05$ ); in ratio relationships, bar chart response time was significantly greater than line charts ( $p<0.05$ ); in interval relationships, pie chart response time was significantly greater than line charts ( $p<0.05$ ).

**Table 6 One-way ANOVA of Response Time for Different News Types (N=60)**

News Type	Response Time
Parallel Relationship	4.687*
Total-Part Relationship	9.591**
Ratio Relationship	3.267*
Interval Relationship	3.023*

Note: \* indicates  $p<0.05$ , \*\* indicates  $p<0.01$ , \*\*\* indicates  $p<0.001$

**3.3.2 Accuracy Results** Chi-square tests on accuracy rates for four data news information chart types found no significant differences in accuracy across chart types within each news data category (see Table 7 ). The table shows: in parallel relationships, sticky note style had the highest accuracy (87.8%) and text style the lowest (68.9%); in total-part relationships, bell style had the highest accuracy (77.2%) and peacock style the lowest (66.7%); in ratio information charts, line charts had the highest accuracy (89.4%) and bar charts the lowest (79.4%); in interval relationships, line charts maintained the highest accuracy (93.3%) and pie charts the lowest (88.9%).

**Table 7 Accuracy Rates for Different News Information Charts (N=60)**

Information Chart Type	Accuracy Rate (%)
Parallel Relationship	2.268
Total-Part Relationship	0.093
Ratio Relationship	0.114
Interval Relationship	0.355

In summary: For parallel relationship data news, no significant differences existed in average fixation count, fixation duration, or subjective satisfaction; text style response time was greater than sticky note and wind chime styles. Wind chime style showed highest accuracy, text style lowest accuracy, and longest time spent.

For total-part relationship data news, no differences existed in average fixation count or duration; subjective satisfaction differences were significant, with bell and turtle styles higher than peacock style. Peacock and turtle style response times were significantly greater than bell style. Peacock style took the longest time and had the lowest accuracy; bell style took the shortest time and had the highest accuracy.

For ratio relationship data news, no significant difference existed in fixation duration, but fixation count differences were significant between bar charts and line charts, with bar charts receiving more fixations. Subjective satisfaction differences were significant, with bar charts and pie charts higher than line charts. Line charts had the highest accuracy, bar charts the lowest, with longer response times.

For interval relationship data news, no significant difference existed in average fixation count, but fixation duration differences were highly significant: pie charts > bar charts > line charts. Subjective satisfaction differences were significant: bar charts > line charts > pie charts. Pie chart response time was significantly greater than line charts, with no significant accuracy differences among the three types. Line charts maintained the highest accuracy, pie charts the lowest.

## 4 Discussion

### 4.1 Top-down Processing and Re-evaluation of Lead Paragraphs in Data News

The experiment found that data news reading trajectories generally follow the common Chinese reading sequence—top to bottom, left to right—with a significant visual blind spot in the lower-right corner. This reading pattern aligns with Renmin University of China’s Communication Psychology Laboratory findings on newspaper layout reading, indicating that data news graphic structure design should still respect gaze flow patterns in Chinese reading contexts, particularly when designing timelines and other flow-oriented graphics. Attention should

be paid to respecting audience reading habits and rationally planning layout to improve reading comfort.

Second, lead sections in experimental images received focused attention from subjects, likely for two reasons: (1) High-density small-font paragraphs attract more cognitive resources. The “EyeTrack III” study noted that large-font content is more likely to be scanned than read, while small fonts can lead to more focused reading. Due to larger text volume and smaller font size creating high information density, these sections easily attract attention. Simultaneously, readers must be more focused and invest more cognitive resources to discern small-font content, resulting in longer average fixation duration and forming key areas in heat maps. (2) News reading experience influences the process; audiences habitually seek event outlines from leads to quickly form basic news cognition. Thus, when reading data news, subjects employed a “top-down processing” cognitive approach, consciously seeking lead paragraphs to quickly understand the information chart’s theme and context.

During the experiment, most subjects were first attracted by news headlines, then continued searching for more information with purpose and questions. Although visualization charts constitute the main body of data news and might first attract readers’ gaze, leads typically provide detailed introductions to the data news theme and background. Under experimental task pressure, subjects likely hoped to obtain frameworks for interpreting data and details of news events from leads, making the lead paragraph still the starting point for content reading. This demonstrates that subjects’ visual processes in reading data news were task-driven, universally exhibiting “top-down processes”—using conventional knowledge and experience from news reading to form expectations or hypotheses about lead paragraphs, which constrained all stages and levels of processing, adjusted information selection and integration, and guided attention to details. As Arnheim noted in *Visual Thinking*, cognition is meaningful: readers’ visual cognition constantly seeks focal points, employs past cognitive experiences in visual processes, and typically views things with purpose.

This finding reveals the value and importance of leads in data news, reminding creators that while emphasizing information visualization design, they should not neglect lead content and writing. Although data news excels at picture-based storytelling, leads remain readers’ focus and become important guides for reading. Creators should more fully condense core ideas and important information in leads to lay foundations for readers’ subsequent chart decoding.

#### **4.2 Visual Effectiveness and Design Strategies for Information Graphics**

Sun Fuchuan’s experiments demonstrated that eye movement is not simply a bottom-up process but already contains top-down processing. For simple geometric figures, the visual system primarily detects key geometric features, with fixations concentrated on special geometric characteristics—contours and cor-

ners. For complex image stimuli, fixation positions depend on subjects' existing knowledge backgrounds and characteristics. This experiment shows that when reading entire data news pieces with relatively complex images, subjects first employed previous news reading experience, concentrating fixations on key content areas such as leads and column titles. This proves that attention plays an organizing and maintaining role throughout the reading psychological process, representing an essential psychological factor for reading cognitive and regulatory processes.

Specifically for single information charts: Text-based data news experiments show that diagrammatic structure differences have minimal impact. Text-based types primarily diagram news, presenting information as textual material regardless of layout, only changing text positions. Overall, readers' attention focuses on parsing textual content. Subjective satisfaction surveys indicate bell style's cognitive effect surpasses peacock and turtle styles, possibly because bell style text is more concise, color schemes clearer, and numbered labels provide some gaze guidance.

Numerical data news experiments for ratio relationships show similar fixation durations across three chart types, indicating similar information extraction difficulty. Fixation count ranked from high to low as: bar chart, pie chart, line chart. Fixation count reflects subjects' attention to charts; higher counts indicate easier noticeability or greater interest. Bar charts' advantage in fixation count suggests subjects may have engaged in deeper information processing, consistent with subjective satisfaction measurements. Bar charts did not achieve optimal cognitive effects but yielded highest subjective satisfaction. Multiple subjects mentioned preferring bar charts in interviews. Bar charts' larger coverage area makes them more attention-attracting, while the varying heights of bars create dynamic visual interest, with subjects stating they "could immediately distinguish the highest and lowest values at a glance." This aligns with findings from *Bars and Lines: A Study of Graphic Communication* that people habitually "use bar charts to describe comparisons between data and line charts to describe trends." Interestingly, despite subjects' preference for bar charts, line charts showed better accuracy and response time metrics, indicating that while bar charts easily activate visual stimulation and trigger information processing, understanding, and search, their relatively independent, non-continuous data requires scanning between different data points for autonomous comparison and judgment. Line charts use lines to show data trends, enabling continuous scanning that reduces cognitive load. This demonstrates that aesthetic preferences and communication usability are not entirely consistent.

Interval relationship measurements show no significant fixation count differences, indicating similar attention attraction among the three chart types. However, fixation duration differences were highly significant, indicating substantial variation in information extraction difficulty. Pie chart fixation duration was significantly longer than bar and line charts, making it the most difficult chart for information extraction. Relative to this, line charts were the easiest, with bar

charts in between. Chart designer Nigel Holmes proposed that line charts show trends, bar charts show comparisons, and pie charts show proportions. However, Tufte stated that pie charts are poor at clearly expressing comparative relationships. This study's results confirm Tufte's assertion. Psychological experiments have proven that in judging overall object characteristics, unconscious perception exhibits shape superiority effects, where "the higher the degree of unconscious or automated processing, the fewer cognitive resources consumed." Bar and line charts' geometric features are more salient than pie charts, thus receiving more fixations and achieving better cognitive effects. Each ratio in pie charts is independent, requiring area size comparisons. Subjects likely needed more effort to correspond values and compare quantitative relationships when viewing pie charts, creating greater cognitive workload, consuming the most time and cognitive resources, and yielding the lowest subjective satisfaction.

Based on experimental data and interviews, this study concludes: Text-based data news focuses on simplifying cumbersome textual information, making clean, orderly layouts that highlight key information crucial for maintaining reading coherence and comfort. In numerical data news, bar charts more easily attract readers' visual attention, focusing on creating holistic impressions that encourage more active information processing. Due to their simplicity, line charts are slightly weaker in attracting visual attention but clearly highlight specific values, focusing on detail presentation. Subjects showed shortest response time and relatively high accuracy, indicating that despite beliefs that "line charts should only show trends" and have "less visual impact than bar charts," subjects could understand data quickly with better memory effects. To enrich visual elements, arrows and other symbols can appropriately increase line chart information volume. Although pie charts can show proportions, they should be used cautiously when proportion differences are not substantial, as readers' cognitive processing consumes the most cognitive resources and presents certain recognition difficulties.

## 5 Research Limitations and Future Directions

This study only examined the extrinsic level of visual elements in data news information charts, with certain limitations in eye-tracking and behavioral experiments. The subject sample range was relatively small, affecting generalizability to some extent. Due to the complexity of data news design and themes, despite controlling for data news information backgrounds, subjective material selection could not be completely eliminated. This study examined reading effects in laboratory settings; when cognitive environments change and different rhetorical situations exert influence, data news reading effects are impacted by multiple factors including theme, color, structure, and shape, representing a more complex cognitive process. Actual design strategies should comprehensively employ diverse visual elements and measurement methods according to rhetorical situations to achieve better reading effects, representing a direction for future research.

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### Author Contributions

**Fang Hao:** Determined research topic and wrote the paper

**Shang Yuanyuan:** Conceived the paper and wrote the manuscript

**Zhang Rui:** Conducted data analysis and revised the paper

**Pang Huishan:** Conducted data analysis and revised the paper

**Yuan Yiling:** Conducted experiments and collected data

*Note: Figure translations are in progress. See original paper for figures.*

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