Postprint: Research on Relevance Criteria for Scientific Data Users

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Abstract

[Purpose/Significance] Based on lens theory and from the perspective of cognitive processing, this study investigates how scientific data users select appropriate data within data sharing platforms. [Method/Process] The research was conducted in two stages. In the first stage, 14 participants were selected to preliminarily obtain a set of scientific data relevance criteria and their usage patterns through semi-structured interviews. In the second stage, 671 questionnaires were distributed to determine the importance of the relevance criteria and to validate the connotations of the criteria obtained in the first stage. [Results/Conclusions] Nine scientific data relevance criteria were ultimately identified: topicality, accessibility, comprehensiveness, timeliness, authority, quality, convenience, standardization, and usability, with their connotations defined and validated. The findings reveal that comprehensiveness and standardization are novel criteria for scientific data; accessibility, usability, and convenience exhibit strong intercorrelations; quality and standardization demonstrate strong correlations; while quality and authority are not correlated, they show consistent judgment trends. In future research, to truly improve retrieval efficiency and enhance retrieval systems, it is essential to explore not only frequently used criteria but also those that are infrequently used yet important.

Full Text

Preamble

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A Study of Scientific Data User Relevance Criteria*

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Abstract

[**Purpose/Significance**] Based on lens theory and from the perspective of cognitive processing, this study investigates how scientific data users select appropriate data from data sharing platforms. [**Method/Process**] The research was conducted in two stages. In the first stage, 14 subjects were selected through semi-structured interviews to initially obtain a set of scientific data relevance criteria and their usage patterns. In the second stage, 671 questionnaires were distributed to determine the importance of these relevance criteria and to validate the connotations identified in the first stage. [**Result/Conclusion**] Nine scientific data relevance criteria were ultimately identified: topicality, availability, comprehensiveness, currency, authority, quality, convenience, standardization, and usability, with their connotations defined and validated. The findings reveal that comprehensiveness and standardization are new criteria specific to scientific data; availability, usability, and convenience are strongly interrelated; while quality and standardization also show strong correlations. Although quality and authority are not correlated, they exhibit consistent judgment trends. To truly improve retrieval efficiency and enhance retrieval systems in future research, it is necessary to consider not only frequently used criteria but also those that are infrequently used yet important.

Keywords: scientific data; information carrier; relevance; relevance criteria
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1. Introduction

In daily life, study, and work, people frequently need to consult materials to solve problems, which raises a fundamental question: how to select relevant information or data. Many scholars have addressed this issue. Similarly, in today's data era, scientific data has become an essential analytical material for daily work, primarily referring to raw fundamental data reflecting the nature, characteristics, changes, and patterns of the objective world obtained through scientific activities or other means, as well as various datasets systematically processed according to different scientific needs. Examples include national statistics across industries, satellite remote sensing data, and genetic data. These data contain vast amounts of information and have become one of the primary information carriers. With the development of scientific data, users still face the challenge of selecting appropriate data.

L. Schamber et al. [1] reviewed literature published over 30 years and concluded that relevance is multidimensional, largely dependent on searchers' information insight and their information needs status. Relevance is also dynamic, as evaluations of things change over time, relying on searchers' judgments of the relationship between information and information needs at a given time. Meanwhile, relevance is measurable if studied from the searcher's perspective, both conceptually and operationally. Different dimensions of relevance require corresponding relevance criteria for measurement. In terms of information carriers, relevance criteria have changed significantly from traditional paper-based text to today's web-based, image-based, music-based, and even e-commerce information. For instance, web-based information requires judgments about diversity or security; image-based information requires judgments about composition or attractiveness; music-based information tends to focus more on personal preference.

From the user's perspective, scientific data users' eyes receive external information stimuli during data retrieval, which is transmitted to the brain for processing, ultimately leading to relevance judgments. In this process, the physical characteristics and forms of information carriers themselves influence relevance criteria. Therefore, as information carriers evolve into scientific data, relevance criteria necessarily change. This study focuses on: (1) identifying scientific data relevance criteria, and (2) examining their connotations and usage patterns.

2. Literature Review

The concept of relevance has long been a challenge in information science and information retrieval. Through extensive research, scholars have recognized relevance as a multidimensional, dynamic, yet systematic and measurable concept. L. Schamber et al. [1] emphasized the importance of context and situation in information systems and retrieval. Situational relevance focuses more on the effectiveness of query objects. For example, in the process of publishing a paper, relevance is at least related to the stages of paper writing and the author's situation, and usually also related to the searcher's status in that situation. Therefore, scholar P. Ingwersen [2] raised an important question: what factors make a document appear relevant upon first encounter or only after a longer period? This is a highly subjective relevance factor, which this paper calls relevance criteria. Many scholars have devoted considerable effort to studying this question.

2.1 Document Relevance

L. Schamber [3] conducted experiments from a cognitive perspective in a multimedia professional work environment to study relevance criteria, a method subsequently adopted by many scholars. T. K. Park [4], C. L. Barry [5], W. Bruce [6], and P. L. Wang [7] all attempted to decompose and define relevance judgment criteria and factors affecting relevance judgment processes through experimental methods. L. Schamber et al. [8] later focused on making criteria and criterion sets more standardized and explicit, publishing a compiled list of 80 relevance criteria summarized from previous literature, categorized into five major categories. C. L. Barry and L. Schamber [9] found many similarities in users' selection of relevance criteria across different situations, suggesting a limited set of universal criteria applicable to various users, task contexts, and target information types. P. Borlund [10] confirmed this finding: two different user groups in different work environments shared the same set of relevance criteria.

2.2 Web Relevance

With the popularization of the Internet in the 21st century, people began searching for information on web pages. Scholars started studying how to design or improve systems to help users find needed information more quickly from vast amounts of web information. C. Silvers et al. [11] found that web users behave differently from searchers in traditional information retrieval systems. S. Y. Rieh [12] obtained three web relevance criteria through combined experimental and interview methods: topicality, information quality, and cognitive authority. A. Tombros et al. [13] discussed criteria used by web users during information queries at an ACM conference. A. Crystal and J. Greenberg [14] studied users' relevance criteria during web searches from a different perspective, selecting 12 users interested in health information and obtaining eight criterion sets including 22 sub-criteria. R. Savolainen et al. [15] proposed new criteria such as reliability, security, and diversity. Y. Kammerer et al. [16] argued that due to the special nature of web pages, besides content information, quality and page type must also be considered.

2.3 Image Relevance

The development of informatization and digitization has driven the growth of digital images, with increasing research on image relevance. M. Markkula and E. Sormunen [17] first studied journalists' selection of image relevance criteria, identifying seven criteria, including technicality and visual impact related to image characteristics. Y. Choi et al. [18] studied criteria for American historical image retrieval, obtaining nine relevance criteria through interview analysis, with image attractiveness and technicality being image-specific criteria. As research deepened, T. Y. Hung et al. [19] set different tasks and ultimately obtained 12 image relevance criteria, with aesthetics, composition, image plot, and appearance related to image physical structure. S. Sedghi et al. [20] used grounded theory to compare image and document relevance criteria, finding that currency, usability, copyright, color, target audience, reliability, information size, quality, and topicality also applied to document retrieval, while orientation, technical information, magnification, and originality were image-specific.

Through this review, we find: (1) There are common criteria across target information types, and relevance criteria in different information carriers are interrelated rather than independent, such as topicality, novelty, currency, and quality; (2) Text relevance research is foundational, as text is the most important and widely used information carrier; (3) Any information carrier has specific criteria related to its physical properties, such as hyperlinks and security for web pages, and technicality and attractiveness for images; (4) Scholars have studied various information carriers, but scientific data as a new carrier remains unexamined.

Therefore, this study investigates relevance criteria for scientific data as an information carrier, considering both inherent text-based criteria and new criteria arising from scientific data's unique properties.

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3. Theoretical Framework and Experimental Design

3.1 Theoretical Framework

American psychologist Egon Brunswik proposed that our senses cannot directly connect with external objects and events but must acquire information through a "lens" between external things and internal intuition [21]. As shown in Figure 1 [Figure 1: see original paper], the left side represents real-world events and objects, the middle represents psychological processes during judgment, and the right side represents corresponding behaviors based on judgment. Based on lens theory, this study explores how to connect sensory stimulation with users' judgments and simulates decision-making through linear combinations.

Traditionally, information judgment and selection are based on relevance judgment models, where users accept or reject information primarily based on whether it meets their needs. Relevance judgment is implicit in user decision-making [22]. According to decision theory, selecting from retrieval results and making final judgments depends on relevance criteria used by decision-makers [23]. Scholars have found that besides topical relevance criteria, users employ diverse criteria in relevance judgment processes.

Inspired by information theory, cognitive psychologists view humans as transmission devices capable of receiving, processing, and refining information [24]. Humans have limited capacity for simultaneous information transmission but can overcome channel limitations through information encoding. Therefore, relevance judgment is a serial processing activity in cognition, and relevance criteria usage is also a serial process.

3.2 Experimental Design

This study employed interviews, scenario reproduction to stimulate user cognition, and questionnaires. Data analysis primarily used NVivo for content analysis and SPSS for quantitative analysis. The experiment consisted of two stages. The first stage involved interviews with 14 subjects from universities and research institutions nationwide (Institute of Geographic Sciences, Chinese Academy of Sciences; Beihang University; China University of Geosciences, etc.), including 1 PhD student, 11 master's students, and 2 undergraduates. Users reproduced their retrieval processes for the "Sharing Cup" competition projects, and interviews were conducted to initially obtain scientific data relevance criteria sets and user definitions of their connotations. The second stage distributed numerous questionnaires to "Sharing Cup" participants to validate the interview findings.

3.2.1 Interview Data Collection and Processing To identify relevance criteria used by users when completing tasks, semi-structured interviews were conducted. Interview content was coded and analyzed using NVivo 11.0 to obtain criteria used during scientific data retrieval and definitions of their connotations.

Relevance criteria are knowledge stored in users' minds, expressed in interviews as instrumental concepts or logical relationships [25], such as "relevant to my research," "see if it can be used," or "very comprehensive information." These conceptual terms were coded as criteria. Based on previous research and definitions, they were named topicality, usability, comprehensiveness, etc. (see Table 1).

3.2.2 Questionnaire Data Collection and Processing The experiment collected 671 questionnaires, with 544 valid responses (81.07% validity rate). Among respondents, 22 were undergraduates, 421 were master's students, 99 were PhD students, and 2 were postdocs. Survey subjects who frequently used scientific data (50% of their work) accounted for 68%, and those who sometimes used scientific data (20%-50% of their work) accounted for 23.9%, indicating strong representativeness.

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4. Results

4.1 Scientific Data Relevance Criteria

Through coding, nine scientific data relevance criteria were obtained (see Table 2): topicality, availability, quality, standardization, authority, comprehensiveness, convenience, usability, and currency.

4.1.1 Topicality is defined as data matching the user's research, including three aspects: content relevance, temporal relevance, and spatial relevance. Scientific data contains content information (e.g., yield, cultivated area for agricultural data) and corresponding temporal and spatial information (e.g., yield in a specific year/location, rainfall on a certain day). Therefore, users must select data relevant to their research content, timeframe, and region. Examples coded as topicality include: "Because there's a lot of data, based on time and region, the earthquake occurred in June 2014, so we looked for cloud-free image data from May, June, July, and August 2014," and "Remote sensing data is huge; for a small area we look for corresponding latitude/longitude, for national coverage we look for national data."

4.1.2 Availability means users can successfully obtain data without external factors preventing access. Obtaining relevant data is the ultimate goal of retrieval; inaccessible data is useless. As R. Savolainen et al. [15] noted, unavailability leads users to directly reject information. Interview findings revealed that barriers include lack of access permissions, missing download links, and high costs. One user mentioned: "We try to choose free data and won't buy expensive high-quality data," while another noted: "The only regret is that it can't be downloaded; full-text reading isn't possible."

4.1.3 Quality refers to the degree of data excellence. S. Y. Rieh [12] identified "usefulness" and "excellence" as two fundamental quality factors. P. L. Wang [7] defined quality as documents being "excellent"—a broad concept difficult to operationalize. Broadly defined, quality may encompass all aspects of data with comprehensive evaluation indicators. In this study, quality is defined by its primary connotation: data being accurate, correct, and valid. Examples coded as quality include: "Currently there's no accurate precipitation figure online," and "Data obtained from detailed statistical approaches."

4.1.4 Standardization refers to whether data classification systems and collection processes meet national requirements or are consistent. As foundational data for scientific research, scientific data serves research work. The standardization of collection processes and classification directly affects work progress. Users mentioned: "We found the data couldn't be organized—ten years of data with different processing methods each year, making it hard to summarize," and "They use national or international standards, which are very standardized for long time-series data."

4.1.5 Authority means users can trust the data, primarily referring to influential individuals or institutions publishing the data. C. Watson [23] argued that cognitive authority influences one's thinking, enabling conscious identification of article quality. Authority has strong subjective coloring, with evaluations varying by person. Users noted: "Finally I look at the data source—if it's from the Chinese Academy of Sciences, I feel more confident," and "When the state spends so much manpower and resources to statistically compile and authoritatively release economic data, the quality and credibility are better."

4.1.6 Comprehensiveness means data coverage is complete without missing elements. Research may require continuous multi-year data or comprehensive indicators; missing any year or indicator prevents task completion. Examples include: "We use datasets with long durations, so we check time series for completeness," and "We look at indicator completeness—complete indicators are adopted, incomplete ones are rejected."

4.1.7 Convenience refers to ease of data retrieval, acquisition, and use. When acquisition costs are low, users prefer that data—the principle of least effort. Facing information, people consciously avoid complex, troublesome, and unfamiliar sources, seeking convenient pathways. Linguist G. K. Zipf [26] demonstrated in 1949 that people take the path of least resistance in information searches. Examples coded as convenience include: "Modis downloads are relatively easy, available both domestically and internationally," and "Our application at the Institute of Geography is quick—no offline application needed, just submitting a form."

4.1.8 Usability means after obtaining data, it can be used without being prevented by cognitive limitations or format issues. Scientific data has diverse formats, high professional requirements, and strong domain-specific cognitive limitations, making usability crucial. Examples include: "This landsat data, though matching time and location, has too much cloud cover to be usable," and "As a geography student, I check if the format has problems."

4.1.9 Currency means data is valuable only within a certain time period; beyond that, it loses value. The same data can differ significantly in nature across time periods, affecting its validity period and determining when it remains effective. Once this period passes, data loses value or its value diminishes substantially. Examples include: "Land use changes, so the most recent data approximates current conditions," and "It would be better if we could obtain more real-time data from departments."

From 14 users' interviews, 518 responses were obtained, with users retrieving 345 datasets. Coding these 518 responses yielded 287 mentions of criteria. Table 3 shows each criterion's frequency, percentage, and number of mentioning subjects. Topicality was most frequently used, followed by quality. The combined frequency of topicality, quality, and availability accounts for approximately 70% of usage, with a few criteria used frequently and most others used occasionally.

4.2 Scientific Data Relevance Criteria Usage and Connotations

Questionnaire surveys revealed the importance distribution of the nine criteria (see Figure 2 [Figure 2: see original paper]). Quality ranked as most important, followed by topicality, with convenience least important. The difference between quality (4.18) and convenience (3.48) is only 0.7 points, indicating respondents considered each criterion relatively important. However, in actual usage, some criteria like topicality and quality are frequently used, while others like authority are rarely mentioned. Thus, usage frequency and importance are not positively correlated.

Comparing usage frequency and importance rankings (see Table 4), the largest gaps appear for availability and authority, followed by convenience. During actual retrieval, users heavily consider whether data is accessible and acquisition costs, yet rate these as unimportant in importance rankings. Conversely, users consider authority important but rarely use it. This suggests that cognitively, users know which criteria yield "optimal" data, but in practice, due to human inertia or environmental constraints, they choose based on "speed" rather than "optimal," seeking maximum benefit with minimum effort.

To validate the accuracy of criteria connotations from the first stage, descriptive phrases from interviews were summarized for 544 subjects to classify (see Table 5). Topicality, comprehensiveness, and currency showed no cross-confusion in descriptive phrases. However, subjects only considered content relevance as topicality and temporal relevance as currency, with spatial relevance not significant. This suggests two points: (1) subjects selected primarily based on literal meaning without deep consideration of phrase implications, and (2) questionnaire wording was not simple and intuitive enough.

For quality, authority, and standardization, credibility belonged to both quality and authority, while "data meets standards" belonged to both quality and standardization. This raises two considerations: (1) whether standardization is a branch of quality evaluation (like accuracy and clarity), and (2) Pearson correlation testing between quality and standardization showed significance (P=0.000), indicating strong correlation at α=0.01 level. For quality and authority (see Figure 4 [Figure 4: see original paper]), Pearson correlation testing showed significance (P=0.162), indicating no correlation, yet both showed consistent trends in some descriptive phrase selections, suggesting essential differences but certain associations—whether more authoritative data has better quality.

For availability, usability, and convenience, usability included convenience phrases (easy to obtain), while availability included all usability phrases (format usability, easy to obtain). The comparative analysis (see Figure 5 [Figure 5: see original paper]) shows all three trends are basically consistent. Pearson correlation testing among them showed significance ($P<0.01$) for all pairs, with availability and convenience correlation coefficient reaching 0.932. The three are closely related: only by obtaining data can usability be assessed, while convenience determines acquisition costs.

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5. Discussion

This study focused on scientific data as an information carrier, identifying nine relevance criteria: topicality, availability, comprehensiveness, currency, authority, quality, convenience, standardization, and usability. Topicality, availability, currency, authority, quality, convenience, and usability are consistent with previous research across different carriers (C. L. Barry [5], L. Schamber [8], P. Wang [27], etc.), representing universal criteria applicable to all information types (documents, images, videos, data, etc.).

The study also identified unique criteria closely related to scientific data's characteristics: comprehensiveness and standardization. Literature reviews revealed no previous studies proposing these criteria for documents, images, web pages, or music. Comprehensiveness focuses on continuity and completeness across temporal and spatial sequences, based on data's time-sensitive and location-specific nature. Standardization emphasizes compliance with unified classification systems and statistical methods, because scientific data retrieval relies on data sharing, and lacking unified standardization systems hinders cross-domain data exchange and sharing [38], affecting retrieval. Scientific data is highly professional and domain-specific; only with unified standards can sharing be better achieved.

Many scholars have mentioned novelty (C. L. Barry [5]; P. L. Wang [7]; A. Tombros et al. [13]; R. Savolainen et al. [15]; M. Twait [41]; C. Papaecconomou et al. [29]; A. R. Taylor et al. [42]; R. A. Hamid et al. [28]). However, this study did not find novelty, likely because scientific data is highly practical—users already know what they need before searching, focusing on utility rather than inspiration.

Regarding usage frequency, topicality and quality are most frequent, consistent with many studies (P. Balatsoukas et al. [32]; S. Sedghi et al. [30]; R. A. Hamid et al. [28]). The combined frequency of topicality, quality, and availability is about 70%, with few criteria used frequently and most used occasionally, confirming the long-tail law (A. Crystal et al. [14]). Although authority is considered important, it is rarely mentioned (A. Crystal et al. [14]), for two reasons: (1) some users cannot distinguish quality from authority, or categorize authority under quality, and (2) after meeting content relevance and quality requirements, users follow the principle of minimum cost, only considering authority when costs are equal. Thus, usage frequency and importance are not proportional (A. Tombros [43]; C. L. Barry et al. [9]).

For criteria connotations, since 1996, L. Schamber et al. [8] noted that influenced by context and subjects, scholars proposed different hierarchical and connotative criteria. Some connotations are clear, but others like quality remain ambiguous. This study defines quality as data being accurate, correct, and valid, while A. R. Taylor et al. [42] considered quality to include five "values": accuracy, comprehensiveness, currency, reliability, and validity. J. E. Klobas [44] proposed four quality components: accuracy, authority, currency, and novelty. S. L. Caudle et al. [45] believed quality includes actual value, perceived value, aesthetics, characteristics, and meaning over time. S. Y. Rieh [12] considered usefulness and excellence as two fundamental factors. Broadly, scholars agree quality evaluates information excellence, but specific connotations vary.

This study preliminarily obtained a set of nine relevance criteria for scientific data. Usage frequency analysis shows topicality, quality, and availability are most frequent. Importance ratings show quality, topicality, and authority as most important, indicating usage frequency and importance are not positively correlated. To truly improve retrieval efficiency, systems must consider both frequently used criteria and infrequently used but important ones like authority.

Through large-scale user classification of criteria connotations, the study preliminarily clarified connotations for topicality, comprehensiveness, and currency. Quality and standardization connotations are highly correlated, showing inclusion relationships. Availability, usability, and convenience connotations are also highly correlated with inclusion relationships. Quality and authority connotations are not correlated but show consistent trends in some descriptive phrase selections, indicating essential differences but certain associations.

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Author Contributions

Zhang Guilan: Responsible for experimental design, data analysis, drafting, writing, and revising the paper.
Wang Jian: Responsible for guiding experimental design, proposing research framework, and guiding paper revision.
Zhou Guomin: Provided paper revision suggestions.
Liu Jianping: Assisted with experiments and later data analysis.
Wei Caoyuan: Responsible for data collection and organization.

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