Graphic resources for health information visualization in the context of Covid-19

Recursos gráficos para visualização de informações de saúde no contexto da Covid-19

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information and technology, information design, information visualization, health, Covid-19

Objective: To investigate the panorama of the use of graphic resources for health information in the context of Covid-19 and the role of Information Design contributions, in convergence with Information Science, in this context. **Method**: The investigation was carried out from theoretical-exploratory research of a qualitative nature with bibliographic searches in the Portal de Periódicos Capes. Articles published in peer-reviewed journals in the last two years (03/2020 – 03/2022), which bring questions related to graphic resources in the context of Covid-19 in the title and in the abstract were selected, to discuss the proposed issues according to the objectives of the article. **Result**: The search carried out on the Capes Periodicals Portal retrieved 87 articles published in peer-reviewed journals, from which 55 addressed discussions related to graphs and information visualization in the context of Covid-19. The articles were categorized according to the approach to related or similar topics and systematized in five tables. **Conclusions**: We were able to draw an overview of publications on graphic approaches related to Covid-19, which indicates that the use of graphic resources to understand phenomena in the health area remains relevant from the first records of these resources until the context of the Covid-19 pandemic.

informação e tecnologia, design da informação, visualização da informação, saúde, Covid-19

***Objetivo**: Investigar o panorama da utilização de recursos gráficos para informação em saúde no contexto da Covid-19 e o papel das contribuições do Design da Informação, em convergência com a Ciência da Informação, neste contexto. **Método**: A investigação foi realizada a partir de pesquisa teórico-exploratória de natureza qualitativa com buscas bibliográficas no Portal de Periódicos Capes. Foram selecionados artigos publicados em periódicos revisados por pares nos últimos dois anos (03/2020 – 03/2022), que trouxessem questões relacionadas aos recursos gráficos no contexto da Covid-19 no título e no resumo, para discutir as questões propostas de acordo com os objetivos do artigo. **Resultado**: A busca realizada no Portal de Periódicos da Capes recuperou 87 artigos publicados em periódicos revisados por pares, dos quais 55 abordaram discussões relacionadas a gráficos e visualização de informações no contexto da Covid-19. Os artigos foram categorizados de acordo com a abordagem de temas relacionados ou afins e sistematizados em cinco tabelas. **Conclusões**: Pudemos traçar um panorama das publicações sobre abordagens gráficas relacionadas à Covid-19, o que indica que o uso de recursos gráficos para compreender fenômenos na área da saúde continua relevante desde os primeiros registros desses recursos até o contexto da pandemia de Covid-19.*

1 Introduction

On March 20, 2020, when the Covid-19 pandemic hit Italy and Spain hard, and preventive measures, such as the use of a face mask and hand hygiene, predominated in conversations, the Doodle – illustration that decorates the home page of the Google search engine in honor of some commemorative date, historical event or birthday of influential people – brought a tribute to Ignaz Semmelweis. The publication attributed recognition to the medical benefits of hand washing discovered by the Hungarian doctor (Google, 2020).

Considered a pioneer in antiseptic procedures in the medical field, Semmelweis played a key role in improving the survival rates of women in the postpartum period as a resident physician at the Vienna General Hospital. Known as the savior of mothers, the doctor and researcher discovered the direct relationship between hand disinfection in obstetric clinics and the decrease in the incidence of postpartum infection in these women, a frequent problem in maternity hospitals in the mid-19th century. Although it encountered some resistance at first, Semmelweis' discovery resulted in the adoption of hand disinfection by medical teams in surgical procedures in different specialties, based on the legitimation of his ideas (Kadar, 2019; Schreiner, 2020).

The incorporation of the so-called aggregate view was revolution in this area, especially in infectious diseases. Doctors and researchers have realized that infections have been responsible for a significant part of the mortality of patients who enter hospitals and that, to face this challenge, medicine needs the so-called aggregate view. This is because physicians are trained to deal with and observe specific problems of individual patients. This prevents the visualization of problems that are only evidenced by an aggregated view of statistical information based on the experience and results of large groups of patients. The aggregate view allows observing what there is in common between data sets and factors and building predictions about the probability of the occurrence of positive or negative events (Haley, 1985).

An important element in Semmelweis' research process was the organization of the information consulted and collected during the investigation in graphs. This organization made it possible for the physician and researcher to compare maternal mortality rates in two clinics that adopted different procedures in relation to the disinfection of the medical staff's hands. Intrigued by the high rate of maternal mortality at the hospital where he began working in the late 1840s and unable to agree with the unsubstantiated theories of his colleagues, the doctor undertook what was likely the first epidemiological study in the history of hospitals. The doctor began his investigation by analyzing 60 years of maternal mortality statistics available at the hospital, from which he found that the increase in rates coincided with the introduction of the Anatomical School of Pathology in the hospital, when cadavers became part of the routine of medical students (Haley, 1985; Newsom, 2001).

The arrangement of the information in a chronological chart allowed the visualization of the relationship between the increase in the number of deaths and the beginning of anatomical activities with cadavers. Obtaining this aggregate view of the situation from an extensive examination of statistical analysis enabled Semmelweis to make relevant inferences that led to strategic changes in clinical practice. Despite the lack of immediate recognition by his colleagues, the discoveries of the Hungarian doctor began to be recognized after his death, at the age of 47, and contributed both to the reduction of deaths from hospital infections and to the adoption of the aggregate view from graphic resources in the health area. Such resources proved to be essential for the recognition of patterns, for the prediction of the evolution of diseases and for decision-making in the health area (Ataman, Vatanoğlu-Lutz, & Yildirim, 2013).

Another historic milestone in the use of graphic resources in medical research was the graphs created and used by nurse Florence Nightingale. Considered the founder of Modern Nursing and the first nursing researcher in the world, her work as a volunteer during the Crimean War, in 1954, had an impact on the research area, especially due to her knowledge of mathematics and statistics, which resulted in relevant publications. Furthermore, Nightingale pioneered the use of graphs in the search for clear and understandable presentations of data collected in her investigations. Her diagram representing mortality rates during the Crimean War is recognized as an important milestone in the history of statistical graphs (Costa, 2009; Magnello, 2012).

Almost two centuries later, graphic resources in the organization of information in health research are still in evidence. From 2020 on, graphs have acquired emblematic notoriety in the context of the new coronavirus pandemic. Health researchers, media outlets and government institutions have used diverse types of graphic resources to analyze the evolution of the pandemic, make predictions and support decision-making by health professionals and public administrators. The contagion curves became part of the media and popular vocabulary, in expressions such as “it is necessary to flatten the contagion curve”, “the curve has risen again”, “we are on a plateau”, among others.

Public health problems such as the Covid-19 pandemic faced by the world from 2020 onwards demand informational solutions of different natures. The use of graphic resources to understand the evolution of epidemic curves in this context has proved to be essential for the analysis and search for solutions. At the same time, problems can impair the effectiveness of the use of these resources: the inadequacy of information visualization resources; the dissociation between the visual artifacts and the informational needs of the subjects; and the inability to assess and understand graphic resources by communities of interest, for example.

The pioneering spirit of Florence Nightingale and Ignaz Semmelweis in the synthesis of health data in medical research was

essential for the gradual development of new languages and means of information visualization. In this context, the knowledge developed in Information Design studies, allied to the area known as Information Visualization, subsidize the production of these informational products with the objective of making them suitable for the desired purposes. Therefore, Health Information Design is a prominent thematic area present in publications and events in the area.

In this scope, studies have found a problem in the lack of interaction between the universe of statistical graphics, on the one hand, and that of information visualization, on the other. Statisticians have been dissatisfied with the simplicity of their graphics in the most modern media, in the face of graphic resources carefully designed by specialists in information visualization. In this sense, the lack of focus on communicating information through graphic resources designed outside the field of statistics has become a concern (Gelman & Unwin, 2013). This type of dilemma finds fertile ground in Information Design, in convergence with Information Science, especially due to the interdisciplinary character of both fields, which focus on solving problems involving information.

Information Design (ID) is a complex concept, which can refer to a discipline as well as a science and a methodology. It is a discipline whose studies aim to satisfy the informational needs of individuals who seek information, through the analysis, planning, presentation and understanding of a message – its content, language and form, regardless of the medium in which it is expressed. In this way, an informational material must satisfy economic, ergonomic, aesthetic, and subjective requirements (Pettersson, 2020). Thus, ID studies present principles and guidelines for the design of objects and information systems, such as the development of graphic interfaces for interaction in digital media, which contributes to their suitability in satisfying the needs of the people who interact with them.

The interdisciplinarity between ID and Information Science (IS) emerges in a complex scenario caused by the emergence of new forms of access to knowledge in digital environments characteristic of Web 2.0 (Oliveira & Author, 2015). Orna and Stevens (1991) investigated this interdisciplinarity and demonstrated how the basic knowledge in ID is valuable for information professionals, both in solving Design problems that arise during their assignments, and in improving relationships working with design professionals. Tramullas (2000) demonstrated how ID, in the digital context, undergoes necessary transformations due to both the complexity of electronic systems and applications, as well as the demands for personalized and specific information for each community of interest. Finally, Orna (2007), in the article Keynote address: Collaboration between library and information science and information design disciplines. on what? Why? Potential benefits?, demonstrates that collaboration between information and ID professionals has great potential to improve the quality and effectiveness of information products.

Most of the data and information collected, generated and/or compiled are made available in digital media. In this context, studies in Information Visualization provide essential contributions to the convergence between IS and ID, which significantly enriches the discussions around the presentation and graphic representation of information in digital information environments, especially in the health context.

In this context, the research question that guided the investigation and the elaboration of this article consisted of: What is the panorama of the use of graphic resources in the context of Covid-19? What contributions can Information Design, in convergence with Information Science, bring to the use of graphic resources in this context? The hypothesis raised here is that graphic resources still support health research and communication, with a prominent role in the context of the Covid-19 pandemic. In this sense, Information Design, in convergence with Information Science, can support the elaboration of graphic resources that help in the analysis of the movement of diseases, in the elaboration of preventive measures and in the support to the solution of informational problems in that scope.

2 Methods

The investigation was carried out from theoretical-exploratory research of a qualitative nature with bibliographic searches in *Portal de Periódicos Capes*. This database was selected because it provides access to a wide range of national and international scientific production, published in high quality peer-reviewed journals, and indexed by the main databases in the world, such as Web of Science and Scopus. It is one of the largest bibliographic collections in the world.

The specific search strategy for understanding the landscape of the use of graphic or visualization resources in the context of the Covid-19 pandemic consisted of searching for the terms "Covid-19" or "corona virus" and "visualization" or "graphics", in Portuguese or English and present in the title, which resulted in the following combination of search terms:

("covid-19" OR "corona") AND ("visua*" OR "graf*" OR "graph")

Two criteria were adopted: peer-reviewed journals and published in the last two years (03/2020-03/2022. 87 articles were retrieved. After reading the titles and abstracts, 30 articles that did not address graphic resources related to the Covid-19 context were eliminated.

Next, we performed a categorization based on the title, abstract and keywords, to aggregate articles that deal with subjects with similar or related themes. We then performed the systematization of the results in tables containing information on title, author, and date, followed by an analysis of the content of the materials present in each

category and comments on relevant information found in the articles. In the last table, we systematized the articles with a single theme, which could not be placed in the other categories, with an extra column with the description of the subject addressed.

3 Results and discussion

Since December 31, 2019, when the World Health Organization (WHO) first learned of the existence of the new SARS-CoV-2 virus, cases of the Covid-19 disease have been reported in 187 countries and 200 territories, with a total of more than 138 million cases and almost 3 million deaths as of April 24, 2021 (Center for Systems Science and Engineering [CSSE], 2021; Wordometer, 2021). The severity of the disease and the high degree of contagion of the virus resulted in the recommendation, by the WHO, of prevention measures already recommended in the SARS (Severe Acute Respiratory Syndrome) pandemic in 2003, given the similarities genotypes between the two disease-causing coronaviruses. These measures were based on studies carried out from different perspectives (Lau et al., 2010; Zhou et al., 2020). Proven effective prevention measures involve isolation, contact tracing, closing schools, reducing mobility and crowded spaces, hand hygiene and the use of masks (WHO, 2021).

The studies that support these recommendations consider detailed analyzes of factors such as age, gender, and mortality rates, among others. Most of these studies employ information visualization means to visually represent the results. Information visualization resources are commonly used to offer representative structures that enable a better understanding of complex data sets, which favors the appropriation of evidence for decision making (Hua, Huang, & Huang, 2019).

The search carried out on the Capes Periodicals Portal made it possible to retrieve 87 articles published in peer-reviewed journals, from which 55 addressed discussions related to graphs and information visualization in the context of Covid-19. The number of articles retrieved indicates the increasing relevance of graphic resources in the context of Covid-19, for different purposes.
The articles were grouped according to the approach to related or similar topics in six categories:

1. Graphic resources used to predict and understand the dynamics of the Covid-19 pandemic spread – 16 articles.
2. Graphic resources to understand aspects related to diagnosis of Covid-19 – 13 articles.
3. Graphic approaches related to drug administration in the context of Covid-19 – 7 articles.
4. Knowledge graphs about literature and databases on Covid-19 – 8 articles.

5. Graphic approaches regarding the causes and effects of measures adopted during the pandemic – 5 articles.
6. Other subjects – 8 articles.

The categorized articles were systematized in six tables, each analyzed in the subsequent paragraph(s). Only the articles mentioned in the text were included in the references chapter.

Table 1 Graphic resources used to predict and understand the dynamics of the Covid-19 pandemic spread – 16 articles

Title	Author(s)	Date
Predicting the Dynamics of the COVID-19 Pandemic in the United States Using Graph Theory-Based Neural Networks	Davahli, M., Fiok, K., Karwowski, W., Aljuaid, A., & Taiar, R.	2021
Graph modelling for tracking the COVID-19 pandemic spread	Alguliyev, R., Aliguliyev, R., & Yusifov, F.	2021
Interactive Analysis of Epidemic Situations Based on a Spatiotemporal Information Knowledge Graph of COVID-19	Jiang, B., You, X., Li, K., Li, T., Zhou, X., & Tan, L.	2022
Spreading of infections on random graphs: A percolation-type model for COVID-19	Croccolo, F., & Roman, H. E.	2020
Construct a Knowledge Graph for China Coronavirus (COVID-19) Patient Information Tracking	Wu, J.	2021
Short-Term Power Load Forecasting Under COVID-19 Based on Graph Representation Learning with Heterogeneous Features	Yu, Z., Yang, J., Wu, Y., & Huang, Y.	2021
Topological and Thermodynamic Entropy Measures for COVID-19 Pandemic through Graph Theory	Nandini, G., Rajan, R., Shantrinal, A., Rajalaxmi, T., Rajasingh, I., & Balasubramanian, K.	2020
Understanding and predicting the spatio-temporal spread of COVID-19 via integrating diffusive graph embedding and compartmental models	Zhang, T., & Li, J.	2021
Combining graph neural networks and spatio-temporal disease models to improve the prediction of weekly COVID-19 cases in Germany	Fritz, C., Dorigatti, E., & Rügamer, D.	2022
Digital Contact Tracing Based on a Graph Database Algorithm for Emergency Management During the COVID-19 Epidemic: Case Study	Mao, Z., Yao, H., Zou, Q., Zhang, W., & Dong, Y.	2021
Interactive web-based graphs of novel coronavirus COVID-19 cases and deaths per population by country	Idogawa, M., Tange, S., Nakase, H., & Tokino, T.	2020
Drawing transmission graphs for COVID-19 in the perspective of network science	Gürsakal, N., Batmaz, B., & Aktuna, G.	2020
COVID-19 Is Not the Flu: Four Graphs from Four Countries	Stojanovic, J., Boucher, V., Boyle, J., Enticott, J., Lavoie, K., & Bacon, S.	2021
Spread of Epidemic Disease on Edge-Weighted Graphs from a Database: A Case Study of COVID-19	Manríquez, R., Guerrero-Nancuante, C., Martínez, F., & Taramasco, C.	2021
Cost-effectiveness of Microsoft Academic Graph with machine learning for automated study identification in a living map of coronavirus disease 2019 (COVID-19) research	Shemilt, I., Arno, A., Thomas, J., Lorenc, T., Khouja, C., Raine, G., ... & Sowden, A.	2021
New concepts of pentapartitioned neutrosophic graphs and applications for determining safest paths and towns in response to COVID-19	Quek, S., Selvachandran, G., Ajay, D., Chellamani, P., Taniar, D., Fujita, H., ... & Giang, N.	2022

The category with the most articles retrieved was *Graphic resources used to predict and understand the dynamics of the Covid-19 pandemic spread*, with 16 articles (Table 1). In this category are articles with graphic proposals used to facilitate the understanding of the dynamics of Covid-19 and the prediction of events related to the disease and the Sars-Cov-2 virus to support decision-making by public bodies and health institutions. health. Next, we comment on one article that stood out for the graphic resources they address and for the conclusions regarding the use of these resources in the context of Covid-19.

In the article *A Visual Approach for the SARS (Severe Acute Respiratory Syndrome) Outbreak Data Analysis*, Hua, Wang, Huang, Hua & Yang (2020) propose a visual approach to the data related to the SARS outbreak that occurred in 2003, in order to understand the results of aspects such as prevention measures and public control policies adopted. This information could support decision-making in dealing with the current pandemic crisis linked to Covid-19. For the authors, visualization methods provide visual syntheses of statistical data that support the challenges involved in the provision of large and dense volumes of information, relevant for decision-making regarding public health reports and treatments. Figure 1 represents a timeline developed in the study.

Figure 1 summarizes the main events related to the SARS outbreak, in which the size of the bars represents the importance of each event. Global WHO announcements and alerts were given more weight, while local events were given less weight, for example. This arrangement of events in a timeline allowed the visualization of causes and effects of each event during the pandemic. From the synthesized data,

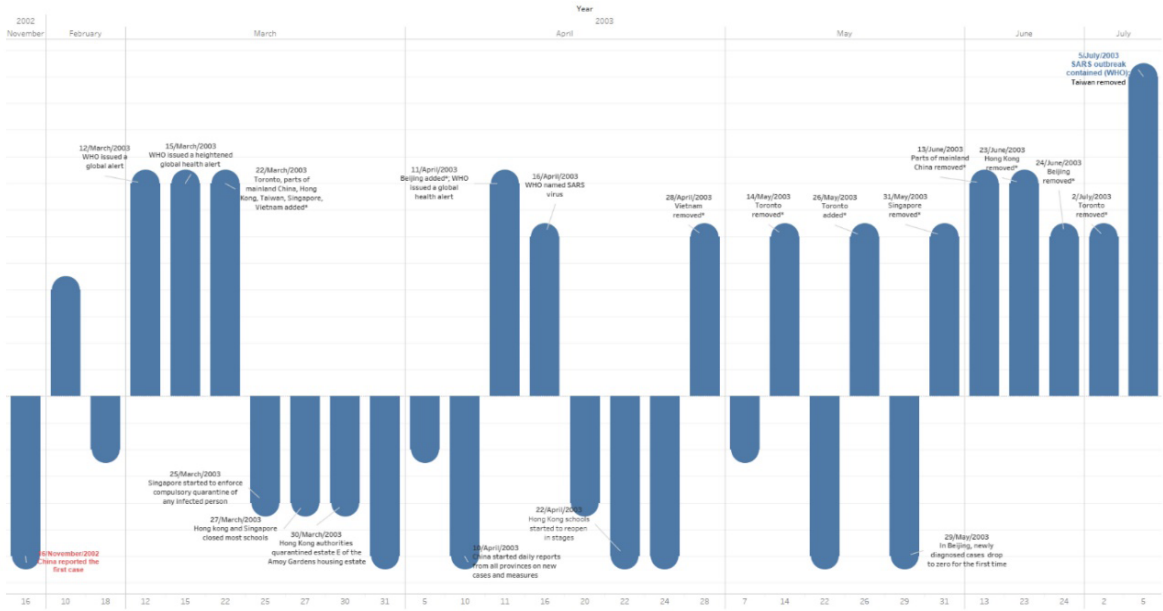

Figure 1 Timeline with the main events during the SARS outbreak (From Hua et al. 2020, licensed under Creative Commons Attribution License)

the authors concluded that prevention measures such as quarantine are the most used control measures, and that areas with stricter measures have shorter disease peaks. Furthermore, the conclusions point out that visual analyzes are useful resources to present and analyze data from the SARS-CoV virus (Hua et al., 2020).

The second category with the highest number of articles was *Graphic resources used to understand aspects related to diagnosis of Covid-19*, with 13 articles (Table 2). In this category are articles with useful graphic solutions to facilitate the understanding and realization of factors related to the diagnosis of Covid-19. Most of the articles provide graphical solutions for diagnostics related to imaging tests, but there are also studies related to blood tests and even doctor-patient dialogues regarding the diagnosis of the disease.

In the article *Pay attention to doctor–patient dialogues: Multi-modal knowledge graph attention image-text embedding for COVID-19 diagnosis*, Zheng et al. (2021) realize that multimodal information (e.g., text, image) should be considered together to make accurate inferences in the healthcare context. The authors propose, then, a multi-modal knowledge graph attention embedding for COVID-19 diagnosis. One of the graphic resources they elaborate is a set of two-word clouds.

Table 2 Graphic resources to understand aspects related to diagnosis of Covid-19 – 13 articles

Title	Author(s)	Date
Pay attention to doctor–patient dialogues: Multi-modal knowledge graph attention image-text embedding for COVID-19 diagnosis	Zheng, W., Yan, L., Gou, C., Zhang, Z., Jason Zhang, J., Hu, M., & Wang, F.	2021
Deep Learning-Based Knowledge Graph Generation for COVID-19	Kim, T., Yun, Y., & Kim, N.	2021
SARS-Net: COVID-19 detection from chest x-rays by combining graph convolutional network and convolutional neural network	Kumar, A., Tripathi, A. R., Satapathy, S. C., & Zhang, Y.	2022
Novel multi-site graph convolutional network with supervision mechanism for COVID-19 diagnosis from Xray radiographs	Elazab, A., Elfattah, M., & Zhang, Y.	2022
Diagnosis of COVID-19 Pneumonia Based on Graph Convolutional Network	Liang, X., Zhang, Y., Wang, J., Ye, Q., Liu,., & Tong, J.	2020
CGENet: A Deep Graph Model for COVID-19 Detection Based on Chest CT	Lu, S., Zhang, Z., Zhang, Y., & Wang, S.	2021
NAGNN: Classification of COVID-19 based on neighboring aware representation from deep graph neural Network	Lu, S., Zhu, Z., Gorriz, J. M., Wang, S., & Zhang, Y.	2022
Explaining machine learning based diagnosis of COVID-19 from routine blood tests with decision trees and criteria graphs	Alves, M., Castro, G., Oliveira, B., Ferreira, L., Ramírez, J., Silva, R., & Guimarães, F.	2021
COVID-view: Diagnosis of COVID-19 using Chest CT	Jadhav, S., Deng, G., Zawin, M., & Kaufman, A.	2022
COVIR: A virtual rendering of a novel NN architecture O-Net for COVID-19 Ct-scan automatic lung lesions segmentation	Amara, K., Aouf, A., Kennouche, H., Djekoune, A., Zenati, N., Kerdjidj, O., & Ferguene, F.	2022
DenResCov-19: A deep transfer learning network for robust automatic classification of COVID-19, pneumonia, and tuberculosis from X-rays	Mamalakis, M., Swift, A., Vorselaars, B., Ray, S., Weeks, S., Ding, W., . . . Banerjee, A.	2021

Table 3 Graphic approaches related to drug administration in the context of Covid-19 – 7 articles

Title	Author(s)	Date
Knowledge Graph-Based Approaches to Drug Repurposing for COVID-19	Al-Saleem, J., Granet, R., Ramakrishnan, S., Ciancetta, N., Saveson, C., Gessner, C., & Zhou, Q.	2021
Drug repurposing for COVID-19 via knowledge graph completion	Zhang, R., Hristovski, D., Schutte, D., Kastrin, A., Fiszman, M., & Kilicoglu, H.	2021
Drug repurposing for COVID-19 using graph neural network and harmonizing multiple evidence	Hsieh, K., Wang, Y., Chen, L., Zhao, Z., Savitz, S., Jiang, X., . . . Kim, Y.	2021
Knowledge-Graph-Based Drug Repositioning against COVID-19 by Graph Convolutional Network with Attention Mechanism	Che, M., Yao, K., Che, C., Cao, Z., & Kong, F.	2021
A potential solution to avoid overdose of mixed drugs in the event of Covid-19: Nanomedicine at the heart of the Covid-19 pandemic	Duverger, E., Herlem, G., & Picaud, F.	2021
Predicting novel drug candidates against Covid-19 using generative deep neural networks	Amilpur, S., & Bhukya, R.	2022
Topological analysis of para-line graph of Remdesivir used in the prevention of corona virus	Liu, J., & Singaraj, R.	2021

The authors used the Natural Language Processing toolkit to count the frequency of the keywords of the two kinds of dialogues – related to the symptoms of Covid-19 and non-Covid-19 patients. From the figure, the authors observed that words used to describe the symptoms of Covid-19 patients are significantly different from the ones used by patients with other diagnoses.

The third category we systematized was *Graphic approaches related to drug administration in the context of Covid-19*, with articles proposing graphic studies related to drug administration associated with Covid-19. In this category are articles with relevant approaches related to issues associated with the seek for effective drugs and therapeutics for treating Covid-19. In this context, much effort has focused on repurposing drugs known for treating other diseases than Covid-19 to save time. So, among the retrieved articles, are studies with graphic approaches to biological and synthetic molecules; to literature-derived knowledge graphs and to evidence regarding experiments with these drugs.

In the study *Knowledge-Graph-Based Drug Repositioning against COVID-19 by Graph Convolutional Network with Attention Mechanism*, by Che et al. (2021), the authors analyze the path between Covid-19 and drug candidates to understand why some drugs are more likely to treat Covid-19 compared to others through a knowledge graph model they developed. The author's data schema of their drug knowledge graph is represented in Figure 2.

First, the authors analyze the original data in the knowledge base to extract the triples. Then, as they describe, they "insert the data according to the graphical data model integration data triples to obtain

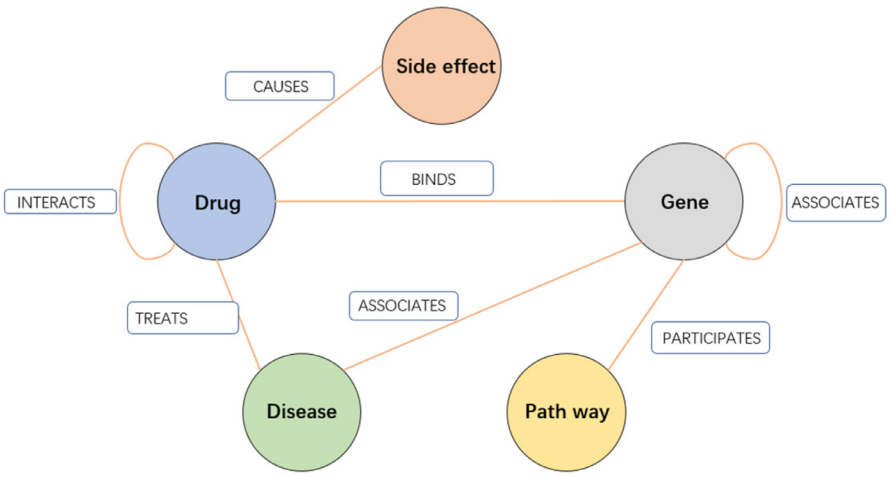

Figure 2 Drug Knowledge Graph Data Schema (Che et al., 2021, open access article distributed under the terms and conditions of the Creative Commons Attribution [CC BY] license)

the knowledge graph. The KG contains five types of entities, including drugs, genes, diseases, channels, side effects, and nine relationships among them." The authors performed drug repositioning experiments for both Covid-19 and other diseases, and their model identified 30 drugs with potential treatment for Covid-19, five of which proved to be clinically effective.

The fifth established category (Table 4) consisted of articles with graphical approaches dedicated to the analysis of the literature related to Covid-19 published in databases to facilitate the visualization and understanding of the corpus of studies published in the context. Among them we find knowledge graphs, network graphs and other graphical approaches. For Chen et al. (2021), extracting knowledge from the biomedical literature and integrating it with relevant information from selected biological databases is essential to obtain information on the etiology, diagnosis, and treatment of Covid-19. In their study, the authors used Semantic Web RDF technology to integrate knowledge about Covid-19 extracted from the literature with relevant biological databases and formalized this knowledge into a standardized, computable Covid-19 knowledge graph.

In the category corresponding to articles with graphic approaches regarding the causes and effects of measures adopted during the pandemic, we included five articles with causal graphic analyses, fuzzy graphs and other graphic approaches related to the prevention measures adopted during the pandemic. Kawamoto, Aoki & Ueda (2021) developed, in their study, a survey framework that allows respondents to post their opinions in a free-form style that can later serve as one of the items of choice for other respondents, as in a multiple-choice survey. The study resulted in an opinion graph that relates opinions and respondents.

Table 4 Knowledge graphs about literature and databases on Covid-19 – 8 articles

Title	Author(s)	Date
Knowledge graphs for integration of biomedical literature and databases	Chen, C., Ross, K., Gavali, S., Cowart, J. E., Wu, C. H., & Lu, Z.	2021
The unknown knowns: a graph-based approach for temporal COVID-19 literature mining	Bayram, U., Roy, R., Assalil, A., & BemHiba, L.	2021
Network graph representation of COVID-19 scientific publications to aid knowledge discovery	Cernile, G., Heritage, T., Sebire, N., Gordon, B., Schwering, T., Kazemlou, S., & Borecki, Y.	2021
A Glimpse of the First Eight Months of the COVID-19 Literature on Microsoft Academic Graph: Themes, Citation Contexts, and Uncertainties	Chen, C.	2020
Developing Pulmonary Rehabilitation for COVID-19: Are We Linked with the Present Literature? A Lexical and Geographical Evaluation Study Based on the Graph Theory	Fusco, A., Padua, L., Coraci, D., Loreti, C., Castelli, L., Costantino, C., ... Giovannini, S.	2021
Knowledge Graphs for COVID-19: An Exploratory Review of the Current Landscape	Chatterjee, A., Nardi, C., Oberije, C., & Lambin, P.	2021
Modeling in the Time of COVID-19: Statistical and Rule-based Mesoscale Models	Nguyen, N., Strnad, O., Klein, T., Luo, D., Alharbi, R., Wonka, P., ... & Viola, I.	2021
COVID-19 Knowledge Graph: A computable, multi-modal, cause-and-effect knowledge model of COVID-19 pathophysiology	Domingo-Fernández, D., Baksi, S., Schultz, B., Gadiya, Y., Karki, R., Raschka, T., ... & Kodamullil, A.	2021

Table 5 Graphic approaches regarding the causes and effects of measures adopted during the pandemic – 5 articles

Title	Author(s)	Date
Graph-based open-ended survey on concerns related to COVID-19	Kawamoto, T., Aoki, T., & Ueda, M.	2021
Causal graph analysis of COVID-19 observational data in German districts reveals effects of determining factors on reported case numbers	Steiger, E., Mussgnug, T., & Kroll, L.	2021
A fuzzy graph approach analysis for COVID-19 outbreak. Results in Physics	Hassan, N., Ahmad, T., Ashaari, A., Awang, S., Mamat, S., Wan Mohamad, W., & Ahmad Fuad, A.	2021
Risk-Aware Identification of Highly Suspected COVID-19 Cases in Social IoT: A Joint Graph Theory and Reinforcement Learning Approach.	Wang, B., Sun, Y., Duong, T., Nguyen, L., & Hanzo, L.	2020
Protection Strategy against an Epidemic Disease on Edge-Weighted Graphs Applied to a COVID-19 Case.	Manríquez, R., Guerrero-Nancuante, C., & Taramasco, C.	2021

The other studies developed graphical approaches to the data regarding prevention and protection measures against Covid-19. As stated by Manríquez, Guerrero-Nancuante & Taramasco (2021) in one of these studies, such approaches allow the establishment of connections between population groups that are essential in both biological and social areas. In the field of health, the importance of recognizing the complexities of community structures has been essential in understanding the social dynamics related to the spread of infectious diseases.

In Table 6, we systematized the articles that we could not include in the other categories. Among them, we find articles with graphic approaches related to Covid-19 and social media posts, its consequences in the financial world, disinformation about the vaccines and subjective questions about policies and feelings related to the disease. In all of them, the graphic resources proved to be essential for the understanding of phenomena related to Covid-19, both to visualize and analyze trends on the phenomena and to visually systematize large amounts of data to facilitate the understanding of their meanings.

Among the articles, we highlight the study by Ericson, Albert & Duane (2022), who developed graphs relating the political affiliation of subjects to subjective interpretations of the graphs about Covid-19. The authors demonstrated that while people may view a graph from a purely mathematical or geometric perspective, subjective interpretations of graphs can be tempered by their political affiliations.

Table 6 Other subjects – 8 articles

Title	Author(s)	Date
Big data directed acyclic graph model for real-time COVID-19 twitter stream detection	Amen, B., Faiz, S., & Do, T.	2022
Utility of Facebook's Social Connectedness Index in Modeling COVID-19 Spread: Exponential Random Graph Modeling Study	Prusaczyk, B., Pietka, K., Landman, J. M., & Luke, D. A.	2021
Dynamic graph in a symbolic data framework: An account of the causal relation using COVID-19 reports and some reflections on the financial world	Nascimento, D. C., Pimentel, B., Souza, R. M. C. R., Costa, L., Gonçalves, S., & Louzada, F.	2021
Sentimental Knowledge Graph Analysis of the COVID-19 Pandemic Based on the Official Account of Chinese Universities	Li, X., Li, Z., & Tian, Y.	2021
Automatic detection of COVID-19 vaccine misinformation with graph link prediction	Weinzierl, M. A., & Harabagiu, S. M.	2021
The scale of COVID-19 graphs affects understanding, attitudes, and policy preferences	Romano, A., Sotis, C., Dominioni, G., & Guidi, S.	2020
The Influence of Emotional Framing and Graph Complexity on Biases in Graphical Memory for COVID-19 Data in a Lifespan Sample	Jiang, O., Whatley, M., & Castel, A.	2022
Political affiliation moderates subjective interpretations of COVID-19 graphs	Ericson, J., Albert, W., & Duane, J.	2022

Therefore, researchers, practitioners and policymakers should keep in mind that when designing visualizations of data related to infectious diseases, it is imperative that data practitioners continually seek to clarify the relationship between how data is presented and how it is subjectively interpreted. So, it is necessary to continually seek new ways to display data ethically that promote shared understanding and minimize biases.

In this section, it was possible to verify several situations in which information visualization graphic resources are used in the context of the Covid-19 pandemic. It was found that these resources help in understanding large volumes of data and in drawing conclusions from different statistical and geographical factors related. Furthermore, such conclusions are relevant for information sharing, both in specialized spheres, such as academia and politics, and in non-specialized spheres, such as social media. In this sense, Information Design, in convergence with Information Science, provides essential resources to improve the efficiency and effectiveness of information products based on their suitability to the needs of individuals. In this context, the interdisciplinarity with Information Science is favorable for the development of studies on the adequacy of these visual resources to the informational needs of each community of interest.

4 Final considerations

The objective of the article was to investigate the panorama of the use of graphic resources in research on Covid-19 and the role of contributions of Information Design, in convergence with Information Science, in this context. The hypothesis formulated included the emphasis on graphic resources as a support in health research, with a prominent role in the context of the Covid-19 pandemic, in addition to the subsidies arising from Information Design, in convergence with Information Science, in the elaboration of these graphic resources for the analysis of the movement of diseases, the elaboration of preventive measures and the support to the solution of informational problems in this scope.

The results of the search on the *Portal de Periódicos Capes* showed that most of the articles with graphic approaches on topics related to Covid-19 focused on questions about the dynamics of the spread of the virus and the disease, diagnostic questions, and studies on possible drugs for the treatment. Other topics included knowledge graphs about the published literature, causes and effects of the protection and prevention measures adopted, and subjective issues and published in digital media.

We were able to draw an overview of publications on graphic approaches related to Covid-19 in this comprehensive database, which indicates that the use of graphic resources to understand phenomena in the health area remains relevant from the first records of these

resources, as demonstrated in the examples of Semmelweis and Nightingale, until the context of the Covid-19 pandemic. In this sense, studies that focus on the continuous improvement of these resources are necessary in terms of providing subsidies for the elaboration of effective and efficient graphic resources for their purposes. Thus, the convergence between Information Design and Information Science can be seen as a fertile ground for the development of research in the health area, enriched mainly by the interdisciplinarity of Information Science as a human and social science.

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