Visualizing Health Risk: Unravelling Preferences for Graphical Formats and Its Link to Comprehension

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Abstract

Risk estimation and discission making are both tasks where tailored communication methods can make a great difference in the perception and comprehension of the presented information. When interpreting graphic formats there seems to be a difference in what people prefer seeing and what works best for understanding the shown information. Our research compared findings of twenty-one articles investigating graphic preference in risk information in healthcare. Taking into account additional factors like graph literacy and numeracy. We only found two studies that looked into the relationship between preference and comprehension of the individual, which showed controversial results so more research in this field is much needed. We therefore also compared our results considering preference to what is known about comprehension of graphs. In the 21 studies that we analysed, pie chart is preferred most often (57%), followed by bar charts (40%). Pictograph was one of the lesser preferred options (31%). Also, both graph literacy and numeracy were shown to have a great effect on understanding and preference of graphs and should therefore always be considered when designing graphs focussed on making health decisions. Literature tells us that pictographs are actually one of the best fitting graphical formats for conveying risk information. This discrepancy in comprehension and preference of certain formats was seen in several other studies. A limitation of our own study is that we only looked at different types of graphs but did not analyse the graphical features. Here also lies a knowledge gap for future research.

Layman's summary

Wanneer we kijken naar het interpreteren van grafieken lijkt er een verschil te zijn tussen wat mensen graag zien en wat het beste werkt voor het begrijpen van de informatie. In dit onderzoek vergeleken we eenentwintig artikelen waarin gekeken werd naar voorkeur voor verschillende formats in risico-communicatie in de gezondheidszorg. We vergeleken dit vervolgens met wat al bekend is over begrip van verschillende soorten grafieken. Daarnaast hebben we gekeken naar aanvullende factoren zoals grafische geletterdheid en numerieke vaardigheden. In de eenentwintig studies die we analyseerden, werd het cirkeldiagram het vaakst als favoriet verkozen (57%), gevolgd door staafdiagrammen (40%). Het gebruik van pictogrammen was een van de minder populaire opties (31%). Uit literatuur blijkt echter dat pictogrammen juist een zeer geschikte optie zijn voor het overbrengen van risico-informatie. Dit verschil tussen begrip en voorkeur voor bepaalde grafieken kwam in meerdere studies naar boven. Daarbuiten vonden we dat zowel grafische geletterdheid als numerieke vaardigheden een grote invloed op het begrip en voorkeur voor grafieken. Wij achten het daarom van groot belang om deze (en nog enkele andere) factoren in overweging te nemen bij het ontwerpen van grafieken in de gezondheidszorg. Momenteel zijn er naar ons weten maar twee studies die gekeken hebben naar de relatie tussen voorkeur en begrip van het individu. Uit deze twee studies kwamen controversiële resultaten, wat laat zien dat meer onderzoek op dit gebied nodig is. Een beperking van ons onderzoek is dat we alleen gekeken hebben naar verschillende soorten grafieken en niet naar de grafische kenmerken per grafiek soort. Ook dit is iets waar toekomstig onderzoek zich op kan focussen.

Contents

Introduction

Communication of risk and decision-making processes rely on tailored communication methods. Here, graphical formats can make a substantial difference in the perceived and actual comprehension of the presented information (Edwards et al., 2011). Previous research already showed that problems with understanding numerical information can often be ascribed to representation of the problem. Familiarizing people with these representations can make a difference in this case (Gigerenzer et al., 2007). This also means that the type of graphical format influences the understanding of the presented information.

In order to make decisions, different visual representations are applicable for communicating different risk messages (Brust-Renck, 2013). Formats for communicating risk can be divided into two main groups, being either numerical or graphical. Numerical can be divided into either percentual (e.g., 4% will develop oedema) or frequential (e.g., 1 in 25 persons will develop oedema). Graphical formats are a less defined concept, but the most common examples are bar graphs, pie charts, and pictographs. Likewise, pictures or infographics can belong to this group (Lipkus, 2007). In previous research, graphical formats have been linked to better understanding and recall of information than numerical formats (Garcia-Retamero et al., 2012; Garcia-Retamero & Galesic, 2010; Lipkus & Hollands, 1999). Consequently, graphs are starting to become more common.

Since a well-known study by Lipkus & Holland in 1999, many studies about visual communication have been performed. Unfortunately, these studies yield conflicting results, preventing a definitive conclusion on the most effective graphical format. Furthermore, when we look at individuals' likelihood for specific graphical formats, there appears to be a diversity in preferences among viewers. Different studies find that different formats are chosen as most often preferred by the participants (Fortin et al., 2001; Hawley et al., 2008; Ferguson et al., 2023). So it seems that the answer of which graphical format is most preferred is not that straight forward either.

Also, what we prefer does not always seem to be in line with what is best for comprehending risk (Feldman-Stewart et al., 2000; Trevena et al., 2013). In the society we live in nowadays, having the option to choose what fits you best has almost become a right. But do our preferences always match with what is best for us? Maybe our preferences in risk communication are not those that lead to best comprehension and accordingly benefit us most.

When measuring comprehension and recall of information you can look at either verbatim or gist knowledge. Blalock & Reyna, (2016) explain that verbatim knowledge captures the exact words or numbers, whereas gist knowledge is about capturing the essence of the message, including its emotional meaning. In other words, verbatim is more about knowing the exact chance of a certain risk, while gist knowledge focusses more on for example comparing risk to others or valuing the height of a certain risk.

Additionally, there are a lot of other components from which we know they influence the understanding of risk or health information shown in graphs. For example age, health literacy, numeracy, graph literacy and gender all affect the understanding of graphs in a noticeable degree (Brown et al., 2011; Hamstra et al., 2015). Numeracy has been defined by Golbeck et al., (2005) as, ‘‘the degree to which individuals have the capacity to access, process, interpret, communicate, and act on numerical, quantitative, graphical, biostatistical, and probabilistic health information needed to make effective health decisions.” Even when numeracy is low, the ability of someone to understand graphs, so ‘graph literacy’, can still be good (Garcia-Retamero & Galesic, 2010). Graph literacy can be defined as ‘‘the ability to understand and present information in the form of sketches, photographs, diagrams, maps, plans, charts, graphs, and other non-textual, two-dimensional formats’’ by Aldrich et

al., (2000). While we know that these concepts are important in comprehension of graphs, little is said about its relationship to preference.

Our research will focus on exploring what is known about preferences for specific graphical formats. Is there a certain format that is preferred above all the others? Additionally, we will take inventory of the effect of additional factors that are known to influence graphical comprehension. Should graph literacy, numeracy and health literacy be taken into account when developing and showing risk communication graphs? Secondarily, we will try to make a connection to what we know about the comprehension of these preferred formats. Is there overlap between what we prefer and what we comprehend best, or do we need to look for an alternative that combines these two?

Our research will help so that in the future, graphs could potentially be designed to capture and maintain the attention of patients. Additionally, we may offer guidance on how much importance should be given to numeracy and graph literacy when creating and presenting risk health information in graphical formats.

Methods

Objective

The main objective of this study is to learn more about what is known about the relationship between preferences for different graphical formats in risk communication and the effect of different visual presentations on comprehension of risk in health information. Additionally, we aim to learn more about the influence of health literacy and numeracy on both the preference for and understanding of graphs.

Information sources

To find relevant studies we did a systemic search on three different databases, being PubMed, CINAHL and Web of Science. These databases were chosen since they were either used in earlier relevant papers (Abukmail et al., 2021; Ancker et al., 2006; Garcia-Retamero & Cokely, 2017; Mbanda et al., 2021) or because they were recommended for this field by the university. The terms that were used included above others; “risk communication”, “graphs” and “preferences”. Since different databases had different systems, a tailored search strategy was used for each database, which can be found in Appendix 1. Additionally, we searched for similar articles by forward and backward citations.

Eligibility criteria

We included studies that looked at preference in either graphical or numerical communication of risk of health-related information. The studies needed to compare at least two types of presentation (e.g., a visual versus numerical or bar chart versus pie chart). There were no criteria for participants in the study. We only excluded studies that solely focused on the preferences of health professionals because we are mainly interested in the preferences and effect in the receiving party. Also, the study had to be in either English or Dutch language since these were the languages that the researcher could understand. Only new research was included, so reviews were excluded. There were no limitations on year of publication.

Data extraction

A custom-designed spreadsheet was made, into which the extracted data was transferred. We extracted 22 outcomes, divided into the following subjects: studies’ characteristics, participants’ characteristics, intervention details and outcome variables. The whole set-up can be found in Appendix 2. The data was then analysed and converted into a table and additional text.

Analysis

In our data analysis, we focussed on the preference for different graphical formats used in the studies. Initially, we sought to identify which type of graph was most frequently favoured. Subsequently, we explored the impact of numeracy, graph literacy and layout on these preferences.

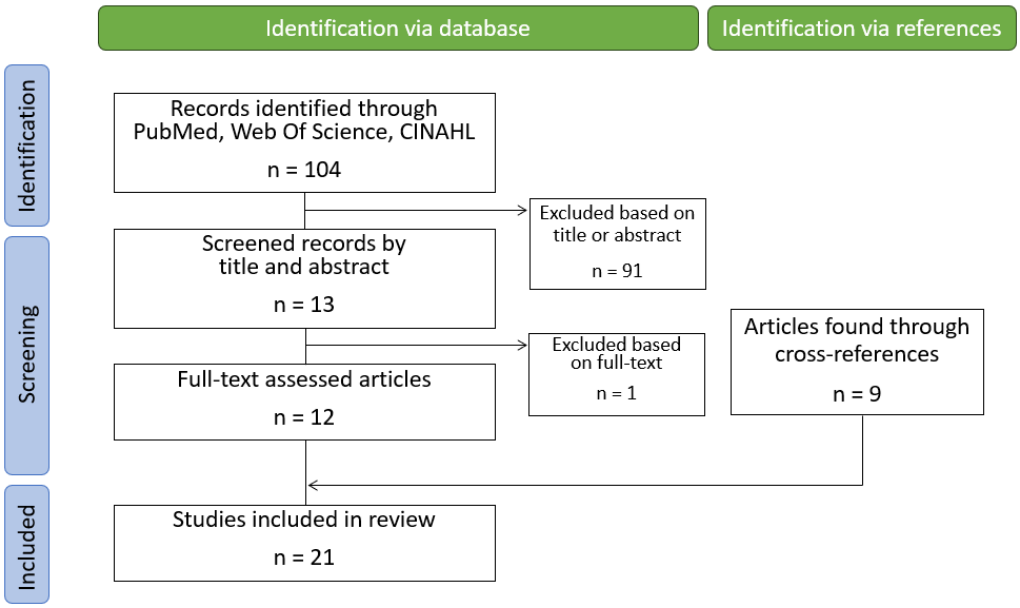
We encountered a limited pool of studies that addressed both individual preferences and comprehension. We therefore later compared the extracted results to existing literature on the comprehension of diverse graphical formats. Thereby, as a second aim, searching for potential correlations between preferences and the comprehension of specific graphical formats.

Results

Systemic search outcomes

The PubMed search produced 57 results of which six met our criteria, Web of Science gave 51 hits of which one was unique and met our criteria, lastly CINAHL produced 27 results of which five were unique and met our criteria. Nine other articles were found through cross-references when reading the introductions of the already included articles. They were not found through our search in the databases since preference was often only a small part of the research and was therefore not always named in the title or keywords. Together this led to a total of 21 eligible studies. The articles were published between 2001 and 2023, of which almost half (nine) were published in the last five years.

Figure 1.
Search outcomes of systemic search in three databases. First articles were identified, after which they were screened. Also, additional articles were added via cross-referencing. This led to a total of 21 included studies.



Participant's characteristics

Table 1 provides an overview of each included study, offering insights into the number of participants, average age, gender distribution, and educational backgrounds. Notably, there is a wide range in

Table 1.

Participant characteristics. M=mean, SD= standard deviation. Men/women is shown in percentage.

Article	Participants (n)	Age Years (%) or M = median	men/women (%)	education level
Hill et al., 2010	19	M = 49	37/ 63	mixed
Dowen et al., 2017	177	20–35 (11%) 36–50 (27%) 51–65 (33%) > 65 (29%)	56/44	mixed
Price et al., 2007	76	M = 19.5 SD = 4.9	28/72	students
Scalia et al., 2021	407	18–34 (26%) 35–54 (36%) > 55 (38%)	40/60	mixed
Henneman et al., 2022	326	M = 41 SD = 11 Range = 18-70	0/100	medium to high
Machida et al., 2022	140	not mentioned	70/30	med students
Etnel et al., 2020	393	M= 26 Range: 18-88	49/51	higher than avg
Waters et al., 2007	2601	M = 44.5 SD ¼ = 12.8	mixed	mixed
Fortin et al., 2001	40	< 45 (15%) 45–55 (60%) > 55 (25%)	0/100	mixed
Gaissmaier et al., 2012	280	M =30	± 50/50	mixed
van Weert et al., 2019	446	M = 58.3	51/49	mixed
Scalia et al., 2019	27	50-65 (41%) 66+ (59%)	44/56	not stated
Barnes et al., 2016	477	M = 50	0/100	mixed
Tait et al., 2010	4685	M = 39	58/42	mixed
Hawley et al., 2008	2412	M = 49 Range: 18–90	48/52	mixed
McCaffery et al., 2012	120	16–20 (15%) 21–35 (24%) 36–50 (38%) > 50 (23%)	41/59	mixed
Schapira et al., 2006	254	M = 57.6 SD = 10.6	0/100	mixed
Ferguson et al., 2023	247	16–30 (31%) 31–40 (65%) 41–49 (4%)	0/100	mostly college
Tait et al., 2012	200	M = 54	± 50/50	mixed
Reading Turchioe et al., 2020	40	M = 61	78/22	mixed
Poirier et al., 2019	45	M = 72	27/73	Not mentioned

participants numbers. This can be attributed to the varied study types (e.g., focus groups, online survey). All except one study collected participant ages. Some studies divided their participant into age groups while other did not take age into account when analysing their results.

Additionally, some studies were performed solely with students or for example pregnant women. Consequently, differences can be seen in the distribution of age between studies. A similar scenario is seen regarding gender and level of education. Again, some studies did take these factors into account when analysing the results, but the majority did not.

We delved into potential relationships between preference and factors like age or gender, but no such relationships were revealed.

Study characteristics

Of the twenty-one studies that we examined it was not al their main goal to examine preference for graphical formats. For some, the central focus lay in understanding different formats rather than on preference. Nonetheless, not all studies that focussed on preference also looked at comprehension. Table 2 provides the objectives of every separate study. Additional information on study characteristics is presented Appendix 3, for a more comprehensive understanding of each study, including nuanced details such as study type and delivery methods.

Table 2.
Objectives of the separate studies.

Article	Objective of the study
Hill et al., 2010	Exploring preferences for sixteen formats of risk representation in focus-groups.
Dowen et al., 2017	Determining the interpretation and understanding of 4 different graphs presenting post transplantation survival data in chronic kidney disease patients.
Price et al., 2007	Determine which features of a 1000 person pictograph diagrams result in the greatest speed and accuracy of graphical perception.
Scalia et al., 2021	To determine the impact of formats on participants' understanding and preference across numeracy and graph literacy subgroups. And rationale supporting participants' preference for each format.
Henneman et al., 2022	Determining format preferences and risk understanding of five formats by a questionnaire at follow-up.
Machida et al., 2022	Exploring participants risk perception, perceived truth of data, and comparative risk perception for either bar or pictograph.
Etnel et al., 2020	Investigating the effectiveness of risk visualizations in conveying verbatim knowledge of single absolute risk.
Waters et al., 2007	Examining accuracy of the ability to determine correctly whether treatment would increase or decrease the total risk in different formats.
Fortin et al., 2001	Elicit patient preferences for the presentation and framing of complex risk information.
Gaissmaier et al., 2012	Improve the understanding of conveying health-related statistical information with graphical representations compared with numerical representations.

van Weert et al., 2019	Investigate preference for graph formats presenting risk information, and the contribution of age, health literacy, numeracy and graph literacy in understanding this information.
Scalia et al., 2019	Test graphical display formats to identify preferred formats and metrics
Barnes et al., 2016	Examine the hypothesis that risk communication methods tailored to individuals' preferences can increase risk comprehension
Tait et al., 2010	Examine the effect of different message formats on parents' understanding of research risks and benefits.
Hawley et al., 2008	Evaluate the ability of graph formats to impart knowledge about treatment risks/benefits to low and high numeracy individuals.
McCaffery et al., 2012	Test graphic risk communication formats for presenting small probabilities using graphics with a denominator of 1000 to adults with lower education and literacy
Schapira et al., 2006	Evaluate the effect of graphic format elements on perceptions of risk magnitude and perceived truth of data.
Ferguson et al., 2023	Assess pregnant and recently pregnant people's understanding and preferences for different risk communication formats.
Tait et al., 2012	Evaluate and compare subjects' understanding and perceptions of risks and benefits presented using animated computerized text and graphics.
Reading Turchioe et al., 2020	Assess hospitalized patients' objective comprehension of text-only, non-graph, and graph visualizations.
Poirier et al., 2019	Identify formats that support clear and accurate risk communication

Preferences

Preferred type of graph

Table 3 provides a comprehensive overview of all the graphical options that were displayed across the twenty-one studies. We first state how many studies included the specific format, then how often it came out as the most preferred option. The last column showcases the percentage of times a format was chosen, calculated as the number of preferences divided by the number of times it was included. We chose this analytical approach due to the great variance in the amount in which certain formats were included in the different studies. By presenting the relative preferences, we were able to compare different formats effectively.

When examining the most frequently preferred graphs across the studies, a considerable diversity is seen. The options that were included in the twenty-one studies are as follows: pie, bar, table, percentage, thermometer, pictograph, clock, and text. Pictograph was one of the options in most studies (sixteen), followed by bar graphs (fifteen). The remaining options were presented in lesser extent: pie was shown seven times, while clock and text were shown six times. Tables, percentages, and thermometers were the least common, appearing only three times.

The bar chart was chosen as preferred most often (six times). In part, this can be attributed to the fact that it was included in the majority of the studies. The pictograph (or icon) was the second most preferred choice, selected five times. The pie chart, although included in only seven times, was the third most favoured option. In relative terms, pie chart was the most preferred option among our studies.

Table 3.
Overview of preferred graph format in different studies. First the type of graph is stated, then in how many studies this graphical format was included. In the third column the number of times it was chosen as most preferred is shown. At last, we show how often it was chosen relatively, which has been stated in percentages.

Type of graph	Included (n)	Preferred (n)	Percentual (%)
Pie	7	4	57
Bar	15	6	40
Table	3	1	33
Percentage	3	1	33
Thermometer	3	1	33
Pictograph	16	5	31
Clock	6	1	17
Text	6	1	17

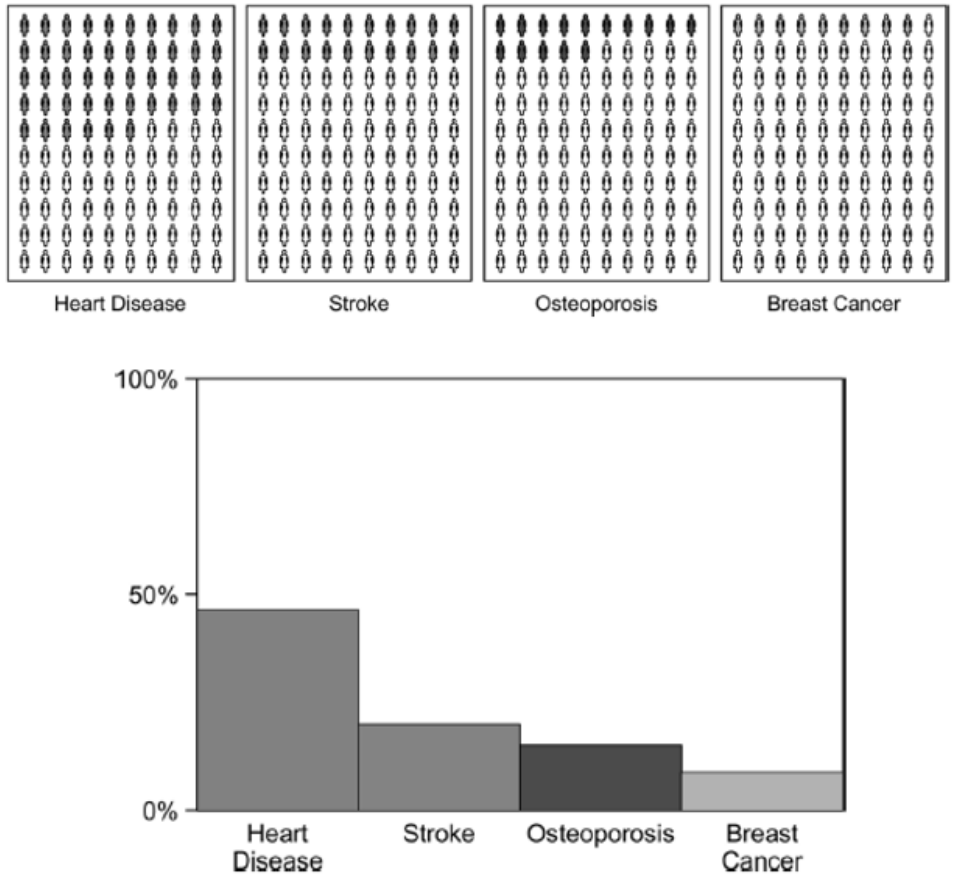
Presenting single or multiple risk

In some studies, graphs displayed only one single condition in one single graph (n=3), while the majority presented multiple conditions within one single graph (n=19). This distinction meant that in the former case graphs display less information, making it more clear and easier to interpret. On the other hand, when showing multiple conditions in one graph, more information will be provided making it easier to compare groups but also making it visually more complicating.

We speculated this difference might influence preference for certain formats. Indeed one of the included studies, by Schapira et al., (2006), found a difference in preference when either presenting single risk or multiple risk. When illustrating the lifetime risk of a 50-year-old woman for developing four different diseases (as shown in figure 2), a bar graph was preferred over an icon array. However, in the same group, when depicting only the risk for developing breast cancer, icon array was preferred over a bar graph. This highlights that different situations led to distinct preferences. In the articles we reviewed, this was the only study that investigated this specific concept.

Then again, the specific way in which multiple risk is presented in a chosen format might also influence this preference. So which features (like colours, numbers, layouts) are added to graphs. In the same study of Schapira et al., when presenting the risk for multiple disease, the icon array displayed four separate fields of 100 icons for each disease. Conversely, the bar graph exhibited a single graph with four separate bars in them (shown in figure 2). Maybe if the risk for all the diseases were displayed in one icon array of 100 icons, preference would have been different. Price et al., (2007) investigated this by showing participants either combined risks in one graph or divided over separate graphs. Their findings indicated that participants preferred combined graphs over separate graphs, underlining the impact of the way information is presented on participants' preferences.

Figure 2.
Showing four separate icon arrays displaying four separate risk for four different diseases. While at the bottom showing the same four risks for developing four different diseases but now combined in a single bar graph.
Altered from Schapira et al. 2006.



Comprehension

Out of the twenty-one studies that we included in our search, seventeen looked at the overall comprehension of the group as well as preference. From these seventeen studies, six found no (significant) difference in comprehension between the different graphical formats. So, not one type of graph yielded better understanding than any of the other graphical formats in their studies. The remaining eleven papers studied comprehension in various ways.

Verbatim versus gist knowledge

Nine studies (Etnel et al., 2020; Ferguson et al., 2023; Gaissmaier et al., 2012; Hawley et al., 2008; McCaffery et al., 2012; Reading Turchioe et al., 2020; Tait, Alan R; Voepel-lewis et al., 2010; Tait et al., 2012; van Weert et al., 2021) also looked at the difference between verbatim and gist knowledge. In these nine studies all but one used (multiple) questions to measure both verbatim and gist knowledge. The majority scored the number of questions answered right and determined if someone had high or low verbatim or gist knowledge. Only Schapira et al. used relative error rates in interpreting the graphs as a measurement of verbatim accuracy.

Due to the limited connections between the various studies and their outcomes on comprehension, as well as differences in study methodologies, we will highlight some of the most noteworthy findings.

Gaissmaier et al., (2012) discovered that only participants with higher graph literacy exhibited better understanding of both gist and verbatim knowledge when presented with graphics rather than numerical information.

Van Weert et al. (2021) and Hawley et al., (2008) both observed that tables lead to a higher verbatim score, compared to other graphical formats. Additionally, where van Weert et al. found that pie charts led to low verbatim scores, Hawley et al. found that gist knowledge was often higher for those who viewed pie charts. They even found that in lower numeracy respondents, pie charts led to more adequate gist knowledge than tables.

McCaffery et al. (2012) did not include pie charts in their study but specifically looked at pictographs. They revealed that pictographs led to better performance on gist tasks compared to bar charts. Likewise, Ferguson et al. (2023) who also looked at bar charts, found that they led to the lowest gist accuracy of all graphical formats.

Tait et al. (2012) explored both verbatim and gist knowledge but did not separately analyse the outcomes for each. However, in their discussion they mention that pictographs led to the best gist and verbatim understanding compared to the other formats in their study.

These results are a great example of how there is still a lot of controversial results considering verbatim and gist knowledge in risk communication. While there are also some that encounter similar findings, comparisons remain challenging due to the diverse formats studied and the varying tests used to measure gist or verbatim knowledge.

Comprehension and preference

When looking at the relationship between comprehension and preference, we see that only in two studies the graphical format that was chosen as most preferable was the same as the one that seemed to be best understood. Almost all the other studies found that the most preferred format of the group was not the format that was shown to be best understood. However, these results are hard to interpret since you look at the preference of the whole group and not every individual. It is therefore more interesting to investigate participants individual preference and their own comprehension of their favourite type of graph format compared to other formats.

Only two of the twenty-one studies investigated this individual relationship between preference and comprehension. The first, Henneman et al., (2020), found a relation between the preferred format and the accuracy of the estimated risk by participants. Women who received their preferred format were slightly better at estimating the risk compared to those who received a different format.

Controversially, Barnes et al., (2016) encountered another interesting finding about preference and comprehension. Women in their study who preferred bar graphs actually were less likely to answer the comprehension questions correct when shown bar graphs, compared to when it was shown in other formats. In other words, when women who preferred bar graphs got their preferred type of graph, their understanding was worse than when shown in another format. Also, those who preferred numeric risk formats did not perform better on comprehension of numeric formats compared to the average of all participants. So, Barnes indicates that preference might not always lead to better comprehension and there may even be subgroups where risk comprehension is worse when presented in the preferred format.

Health literacy

Among the 21 studies that were included in our research, most (fourteen) did not mention health literacy in their research. Two did mention it in the intro or conclusion but did not measure it in their design. The remaining five studies that measured health literacy did so employing various tools. While some studies categorized participants into different levels of literacy, others only addressed the effect of health literacy in their discussion.

Health literacy can be measured with multiple tools. In our search we encountered four formats. First, the Communicative and Critical Health Literacy (CCHL) by Ishikawa et al., (2008) was used by Machida et al., (2022). Second, the Three questions by Chew et al., (2004) were used in two studies (Reading Turchioe et al., 2020; Scalia et al., 2021). Third, Tait et al., (2012) used the Rapid Estimate of Adult Literacy in Medicine (REALM)(Davis et al., 1993). At last, the Short Assessment of Health Literacy in Dutch (Pander Maat et al., 2014) was used by van Weert et al., (2021). All these tests use a set of questions or tasks that need to be performed by the participants. Ranging from tasks such as reading medical terms aloud to answering question about their understanding of medical information. The challenge in comparing the results across the studies, lies in the fact that each operates on a different scale. Consequently, scores from different tests cannot be directly compared to one another.

Reading Turchioe et al., (2020) and Scalia et al., (2021), measured that respectively 55% and 60% of their group had an inadequate level of health literacy. Tait et al., (2012) found an average score of 65 on a scale of 66 for health literacy, where lower than 60 is seen as in adequate. The first two studies used a different method for measuring health literacy than the latter one did. Machida et al., (2022) again used another format for determining health literacy but also divided their participants in either high or low health literacy. They found that in the lower health literacy group “the truth of the data was perceived as significantly higher for the pictogram ($p = 0.03$) compared with the bar graph.”

Bear in mind that a lot of these factors stand in relation to each other. By way of illustration, Van Weert et al., (2021) found that higher health literacy scores were related to higher verbatim and gist knowledge. This makes it harder to take these factors into account as a single element influencing comprehension as well as preference.

Numeracy

Numeracy was taken into account in more studies when compared to health literacy. Only six studies did not mention numeracy at all (Dowen et al., 2017; Ferguson et al., 2023; Fortin et al., 2001; Hill et al., 2010; Price et al., 2007; Scalia et al., 2019) and six more did mention it but did not measure it (Etnel et al., 2020; Henneman et al., 2020; Machida et al., 2022; McCaffery et al., 2012; Tait, Alan R; Voepel-lewis et al., 2010; Waters et al., 2006). In the remaining nine studies numeracy was measured and taken into account in different ways. Here again, different kinds of measuring formats were used to determine numeracy. Most commonly used was the subjective numeracy scale (SNS) (Fagerlin et al., 2007).

Almost all studies that exploited this relationship found that higher numeracy meant better understanding (Barnes et al., 2016; Hawley et al., 2008; Scalia et al., 2021; Tait et al., 2012; van Weert et al., 2021). Still, this effect was not seen in all studies. (Gaissmaier et al., 2012; Poirier et al., 2019)

Hawley et al., (2008) looked at numeracy and its relation to the comprehension of separate graphs. They found that in groups with lower numeracy, table and pie were best understood, followed by pictograph. When it comes to preferences, Scalia et al. (2021) found that people with high objective numeracy more often preferred bar graphs. Controversially Barnes et al., (2016) found that the

average numeracy score of participants choosing bar or pictogram was lower than those preferring percentages.

Additional influential factors

We extracted additional data on the design of the graph and intervention details, which were documented in the datasheet. The extra information included the colour in which graphs were displayed, how many groups were shown in each graph and if exact numbers were shown. Also, we stated how the graphs were shown (e.g., online or in person) and how the group of participants were recruited. Despite gathering this data, we did not see a direct effect. Given the multitude of factors we already considered, we opted to not explore these results further. Still the detailed data is present in the datasheet provided in Appendix 3.

Discussion

Preferences

Our main finding considering preference for different graphical formats, is that not solely one format can be stated as most preferred since there are various factors influencing studies on preference. In the 21 studies that we analysed, relatively pie chart is preferred most often, followed by bar chart. Bar graph is also one of the formats that is included in most of the studies, probably since it is one of the most well-known formats. In their study Mbanda et al., (2021) state that familiarity is an important aspect in the use of visual aids. Ancker et al., (2006) also reveal that viewers prefer familiarity but that in fact it is not associated with accurate quantitative judgements. On the other hand, pictographs are included in most of the studies (16 out the 21 studies) but is chosen less often compared to bar chart. Ancker et al., (2006) points out that pictographs were reported as less familiar, which might explain why they are less preferred.

Additionally, Price et al., (2007) and Schapira et al., (2006) also showed that the type of information shown within a certain graphical format has an influence on what format is preferred. For example, when showing multiple groups, participant preferred bar graphs instead of icons for single risk. Also, the way the information is displayed in the graphs has a great effect on if participants liked of dis-liked certain graphs. We did not look further into the graphical design of every graph since there was already a lot of aspects that need to be considered and our data was too complex to compare this as well.

Importance of additional factors

One crucial aspect that has been demonstrated to be highly important when displaying risk in graphical formats is graph literacy. It was shown by Gaissmaier et al., (2012) that when graph literacy was low, adding graphs to numerical information had no effect at all. Therefore, focussing on patients graph literacy might be more important than focussing on their preferred type of graphs.

Higher graph literacy is not closely linked to being more familiar with them. Since familiarity often leads to preference for that particular option over others, familiarizing patients with graphical formats that are proven to be effective might be one way to let preference and comprehension overlap. Future research should therefore also include familiarity when discovering the role of different graphical formats.

Aside from graph literacy, health literacy, numeracy, and age all also play an important role in understanding and preference for graphical formats. Therefore, these components should also be included in future research within this field. In the case of health literacy, it is also important to come

up with one uniform tool to test this, making it easier to compare results from different studies. We recommend the Three questions by Chew et al., (2004) since it is short and therefore easy to incorporate and it is already used in multiple studies. Table 3 shows all the additional factors of which we think that they should always be included in future research and development of graphical formats.

Table 2.
Showing different factors that should be considered when designing and presenting information in graphical formats.

Variables	
Graph literacy	One of the most important aspects to consider since it is influenced by some of the other variables and is crucial in understanding any graphical format.
Health literacy	Now measured by different tools. Personally, we recommend using the three questions by Chew et al., (2004). It is commonly used and an easy option to implement in further studies since it holds only three questions.
Numeracy	The Subjective Numeracy Scale (SNS) by Fagerlin et al., (2007) can be used to measure this. While graphicy may be more important, we still think numeracy should be taken into account as well.
Age	Age has been proven to influence interpretation of graphs in multiple studies and should therefore always be taken into account when designing and especially presenting graphical formats. Many diseases are related to age so a lot of risk information is especially focussed on an older age group.
Purpose of the graph	The purpose of the presented information is of great importance as well. Do you want to persuade, warn, or just compare different treatments. Different graphs fit different purposes.

Discrepancy between preferences and understanding

Pie charts

Since pie chart seems to be a preferable option for conveying risk information, we searched literature for what is known about the understanding of pie charts. Both positive and negative aspects of pie charts could be found.

To start with the positive effects of pie charts, they are proven to be useful for certain specific purposes like showing relative magnitude of multiple diseases. Each colour in the pie chart can be used to represent a certain condition in this case. Additionally, research shows that pie charts are associated with more adequate gist knowledge compared to tables. Since gist knowledge is of greater importance than verbatim knowledge in decision making, pie chart might actually work well for conveying risk information. (Brust-Renck et al., 2013; Hawley et al., 2008)

On the other hand, participants are least accurate at judging the larger of two quantities when looking at a pie chart compared to other formats. Besides, bar graphs and icon arrays are shown to work better for conveying relative risk compared to pie charts (Hamstra et al., 2015; Ancker et al., 2006; Brust-Renck et al., 2013) Additionally, a limitation of pie chart is that they are not fit for showing standard deviation. Therefore, pie charts might not always be the best choice for showing certain types of information where uncertainty is an important aspect.

Pictographs

We also searched literature to find out what is known about the comprehension of pictographs. Pictographs, while less commonly known, are often shown to be best understood. Icon arrays, or pictographs, tend to be an “all purpose” type of visual aid. They are especially helpful in making the denominator clear. So, if seven patients out of fifty patients develop side effects, this type of graph will indeed show all fifty separate patients as icons. Therefore, pictographs seems an excellent option for

showing risk information in health care. (Dowen et al., 2017; Hawley et al., 2008; Price et al., 2007; Tait, Alan R; Voepel-lewis et al., 2010; Garcia-Retamero & Cokely, 2017; Brust-Renck et al., 2013)

Where pictographs seem to be one of the more preferable options in case of understanding, it is actually one of the least preferred formats in our reviewed articles. While it was shown in most of the studies (16 out of 21), it was the most preferred option in only five studies (31%). Hamstra et al., (2015) also noted this difference in understanding and preference. In their study pictographs were reported as less familiar. This might also be where the lack of preference comes from, since we tend to prefer thing we've seen more often and are therefore familiar.

Combining literature about comprehension of graphs and the results from this study, has made us conclude that there seems to be a discordance in preference and comprehension of graphs in risk communication. Graphical formats that have been shown easy to comprehend are not necessarily the formats that are most preferred and the other way around. However, this conclusion again comes with a side note that there are numerous aspects affecting both comprehension and preference. Emphasizing again, the importance of keeping in mind the purpose of the graph.

Indications and future research

Our study, combining literature about preference for graphical formats in risk communication, can be used as guiding principles for risk information developers. We advise that instead of looking at patient preferences, focus should be on the level of graphical skills in the target audience. Also, simpler graphs may be preferred but are not always best for conveying gist knowledge. Since gist knowledge is most important in decision-making, graphs should be focussed on conveying higher gist knowledge instead of verbatim knowledge. Therefore, we recommend that when designing new graphs, testing gist knowledge should be used to test effect size.

For future research, there are still many gaps in literature. Only two studies investigated the relationship between preference and comprehension of the individual. Future research should therefore focus on questions like: If patients get to see their preferred format, are they better at estimating the risk and interpreting it? The two studies that we found that looked into this relation found controversial results so more research is desired.

Also, research into communication brings along multiple factors that affect understanding as well as preference. These factors, like health literacy, graphicy and numeracy, are not always measured or at least not in one uniform way, making it hard to compare. Therefore, we suggest choosing one single format for measuring these factors, thereby making the differences between studies in this field smaller.

Limitations

A limitation of our own study is that we only looked at different types of graphs but did not analyse the graphical features. We did collect some information about colours and the showing of exact numbers, and standard deviation, but due to the already so high heterogeneity of the studies we did not look further into these results. While Feldman-Stewart et al., (2000) says colours don't affect accuracy, Ancker et al., (2006) did point out that concepts like scientific uncertainty are often unfamiliar to laypeople and when shown (or not shown) in graphs might alter their preferences. In the twenty-one studies that we investigated not one showed standard deviation in their graphs.

Another limitation of this study, but also overall in this field, is the use of different measuring formats. For example, for measuring health literacy four different formats were used in the five studies where health literacy was measured. This makes it hard to compare studies. The same can be seen when measuring verbatim and gist knowledge.

Overall, risk communication is a field with unlimited different options and aspects that need to be considered. Numeracy, graph literacy, health literacy, age, gender, and ethnicity (of which the latter is not even named in the rest of our review) all affect the way you see and interpret things. Then on the other side, types of graphs vary in their design, the information they display and the way they are delivered. This makes it hard to compare and find a "one fits all format." Also, in different studies, different formats are shown and not all studies include the same formats. This makes it hard to compare them since they all show a variance of the possible choices.

Conclusion

Our main finding considering preference for different types of graphs, is that not solely one format can be stated as most preferred since there are various factors influencing preference. In our study, pie chart was the most preferred option, followed by bar graphs. Pictographs seem like the best understood format, but they are not preferred that much. This might be due to the fact that viewers prefer familiarity in graphs and pictographs are not that commonly known. Multiple studies noted this discordance in preference and comprehension of graphs in risk communication. Also, graph literacy is a very important aspect in understanding but also preferring certain graphical formats so a lot can be gained from familiarizing patients with health information shown in graphical formats. Our study, synthesizing insights from existing literature on graphical preferences in risk communication, provides valuable guiding principles for risk information developers. By acknowledging the intricate interplay of familiarity, comprehension, and preference, developers can create more effective and engaging graphical materials for diverse audiences.

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