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Preference for and understanding of graphs presenting health risk information. The role of age, health literacy, numeracy and graph literacy

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ABSTRACT

Objective: To investigate 1) younger (< 65) and older (≥ 65) adults' preference for and understanding of graph formats presenting risk information, and 2) the contribution of age, health literacy, numeracy and graph literacy in understanding information.
Materials and methods: To assess preferences, participants ($n = 219 < 65$ and $n = 227 \geq 65$) were exposed to a storyboard presenting six types of graphs. Understanding (verbatim and gist knowledge) was assessed in an experiment using a 6 (graphs: clock, bar, sparkplug, table, pie vs pictograph) by 2 (age: younger [<65] vs older [≥65]) between-subjects design.
Results: Most participants preferred clock, pie or bar chart. Pie was not well understood by both younger and older people, and clock not by older people. Bar was fairly well understood in both groups. Table yielded high knowledge scores, particularly in the older group. Lower age, higher numeracy and higher graph literacy contributed to higher verbatim knowledge scores. Higher health literacy and graph literacy were associated with higher gist knowledge.
Discussion and conclusion: Although not the preferred format, tables are best understood by older adults.
Practice implications: Graph literacy skills are essential for both verbatim and gist understanding, and are important to take into account when developing risk information.

1. Introduction

Active patient involvement in medical decision making has become increasingly important [1,2]. This can be particularly challenging for older people, who face many, often complex, health-related decisions [3–5]. Clinical guidelines need to place emphasis on both benefits and harms, to enhance a careful consideration of treatment options among older people and the willingness to comply [6]. Accurate and balanced information about intervention benefits and harms provides patients with the opportunity to develop realistic expectations and to make informed decisions [7]. Commonly used tools to support informed decision making are decision aids [8]. Systematic reviews show that decision aids improve people's knowledge about treatment options, accurate risk perception, participation in decision making and decrease decisional conflict [8,9]. However, the effects are smaller in older than in younger populations, possibly because most decision aids are not specifically tailored to older people (65 years and older) [9].

A specific component of decision aids is the use of graphical risk information, as strongly recommended by the International Patient Decision Aid Standards [10,11]. Graphs are considered an appealing way to present quantitative information because they exploit rapid, automatic visual perception skills [12,13]. From a dual coding perspective, combining verbal (e.g., written text) with visual (e.g., graphs) information is superior to verbal information only, because verbal and visual cues are stored in one's memory separately [14]. This will reduce cognitive load [15] and consequently increase the likelihood that information is

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understood [14]. Reducing cognitive load is especially important for older people due to decreased cognitive capacity with ageing [16]. Six commonly used graph formats are 'clock', 'bar', 'sparkplug', 'table', 'pie', and 'pictograph' [17; see Appendix A]. Findings from a systematic literature review show that the most studied graphs are pictographs (also named icon arrays) and bar graphs. These graph formats improve patients' satisfaction and understanding [18]. However, although the use of graphical formats to present health risk information seems particularly important for older adults, graphical risk presentation formats have hardly been evaluated in older populations [9].

Patient *preferences* for graph formats are important because preference may reflect higher perceived relevance, familiarity, usefulness, usability, and meaningfulness [19]. Hence, preferred formats may be more successful in attracting people's attention [19] and improving information processing [20]. This is expected to promote systematic (i.e., making a judgement by carefully examining arguments) rather than heuristic processing (i.e., using simple decision rules). According to the Heuristic-Systematic Model, judgements arrived at systematically tend to be more stable than judgments arrived at heuristically [21,22].

Increasing *understanding* of graphs is important as well. Adequate information provision [23] and recall of information, i.e. understanding and correctly reproducing information, has been associated with better treatment adherence [24,25]. The Fuzzy-Trace Theory states that after exposure to a meaningful stimulus (e.g., a graph), two types of representations of the stimulus are encoded in memory: verbatim and gist representations. These representations are first encoded in working memory and ultimately transferred to long-term memory [26]. Verbatim knowledge captures the exact words, numbers, or images, whereas gist knowledge captures the essential, bottom-line meaning. In the context of understanding of graphs, verbatim knowledge can be defined as the ability to correctly read numbers from graphs to understand a specific risk or benefit, while gist knowledge can be defined as the ability to identify the key message of the information presented [17]. Both verbatim and gist knowledge are associated with high quality decision making, where the association with gist knowledge seems to be even larger than with verbatim knowledge [17,26,27].

Therefore, the first aim of this study is to investigate younger (< 65) and older (≥ 65) adults' *preference* for and *understanding* of six commonly used types of graph formats presenting health risk information: 'clock', 'bar chart' (from now on 'bar'), 'sparkplug', 'table', 'pie chart' ('pie'), and 'pictograph' [17].

Since older adults experience on average more difficulties in information processing compared to younger adults, especially when processing factual and statistical information [10], this might result in misunderstanding and reduce the likelihood that they will make a truly informed decision. However, understanding of information is not only expected to be influenced by age, but also by health literacy, numeracy and graph literacy. Among older adults, health literacy and numeracy seem to be independently associated with health performance and decision making [28]. *Health literacy* is the degree to which individuals can obtain, process, understand, and communicate about health-related information needed to make informed health decisions [29]. As such, health literacy has been shown to be a critical component of meaningful health risk communication [30,31]. Older people generally seem to have lower levels of health literacy and numeracy than their younger counterparts [32]. *Numeracy* is the ability to understand probabilistic and mathematical concepts [30,33,34]. People with low numeracy are less able to understand probabilities, percentages, and frequencies [34], to perform mathematical calculations [34], and to interpret numerical information needed to understand risk information [35] including the risks of side effects [36]. Studies suggest that numeracy might be lower in an older population due to age-related changes in analytic processing and reasoning [14,37]. Recently a related concept was introduced: graph literacy [38]. *Graph literacy* is the ability to evaluate and extract data and meaning from graphical representations of numerical information [36,38], which is another important component of one's ability to accurately evaluate and understand information about risk [36]. While visual displays of health risk information might mitigate the effects of low numeracy, this is not true for low graph literacy [39], because people with low graph literacy have poorer understanding of numerical information when it is presented in graphical format instead of numbers [40,41]. These different types of literacy, in addition to age, are likely to impact people's ability to interpret and understand health information [30] and to make an informed decision [36]. Although some previous studies have measured different types of literacy jointly [e.g., 36,42], this was mostly not in older adults. In addition, results may not generalize due to study limitations such as overrepresentation of high education levels [42].

The second aim of this study is therefore to examine to what extent age, health literacy, numeracy and graph literacy as measured in a well-balanced sample contribute to *understanding* of risk information presented in a graph.

2. Methods

2.1. Procedure and design

Participants ($N = 446$) were recruited by the ISO-20252 (formerly ISO-26362) certified market research company PanelClix. PanelClix has a large active panel in the Netherlands with around 100.000 active members with extensive member profiles (see https://www.panelclix.co.uk/). Inclusion criteria were: 1) being 18 years or older; 2) being able to read and write in Dutch.

The online survey started with measuring background variables and control variables about medical education and knowledge. In the next part of the study, participants' preference for type of graph format was assessed. Participants were asked to imagine the following scenario: "*Imagine that you have been diagnosed with cancer. The doctor gives you two treatment options: radiotherapy or surgery. Both treatments have a risk of side effects. Below you will see pictures with information about the risks of both treatments. We would like your opinion on the way the information is presented in the graphs. The information that is given in the different graphs is exactly the same*". All participants were then exposed to a storyboard with six sets of graph formats with numerical information showing the risks of the two treatment options. These formats were all displayed simultaneously on the screen, but presented in a random order to avoid bias of presentation order (see Fig. 1). Participants were asked to choose the set of graph formats that was most appealing to them. Each of the six sets compared the same information about risks of radiotherapy and surgery, but differed in graph format. The six graph formats were based on those used in the study of Hawley et al. [17]: 'clock', 'bar', 'sparkplug', 'table', 'pie', and 'pictograph'. To make sure that the risk information was realistic, this information was retrieved from a decision aid at the website Med-Decs, a database for worldwide decision aids [43].

In the next part of the study, an experiment was conducted to examine the effects of graph format on understanding. A 6 (graph format: set of clocks, bars, sparkplugs, tables, pies, and pictographs) by 2 (age: younger [< 65] vs older [≥ 65]) between-subjects design was used. Participants were now asked to imagine a hernia scenario describing the risks of side effects of two treatment options: medication and surgery. Based on the background characteristics, a stratified sample was created in

Fig. 1. Storyboard with graph formats (presentation order of the graphs was random).

which different age groups (younger [< 65] vs older [> 65]), gender (female vs male) and education (low vs middle vs high) were equally represented in each condition. Participants were first stratified on age, gender and education, and then, in the experiment, randomly exposed to one of the six sets of graph formats that compared the risks of the two hernia treatment options (see Meppelink et al. [44] for a similar stratification procedure). Hence, participants only saw one set of graphs in this part of the study. The risk information in the hernia scenario was retrieved from existing guidelines of the Care Institute Netherlands [45]. Appendix **A** depicts the stimulus materials. After being exposed to one of the six conditions, understanding information in the graph (operationalized as verbatim and gist knowledge) was measured. Finally health literacy, numeracy, graph literacy and the remaining control variables were assessed. Ethical approval was provided by the research institute of the first author (2017-PC-8669).

2.2. Measurements

2.2.1. Dependent variables

Preference for graph format was assessed by asking participants to choose the set of graph formats that was most appealing to them based on their first impression.

Understanding was measured with *verbatim knowledge* and *gist knowledge* while the graphs remained on the screen. Verbatim knowledge was measured with four open-ended questions related to the number of people expected to have a side effect [17]. An example question is: ‘If 100 people choose medication, approximately how many would experience thrombosis?’ Each answer was coded as either 1 (correct) or 0 (incorrect). Following Hawley et al. [17], we considered answers within two points above or below the actual correct number as correct (value = 1). A total verbatim knowledge score was calculated by taking the sum of the correct answers (range 0–4). Gist knowledge was measured with two multiple choice questions related to comparing the treatment options and indicating which treatment would yield the best or worst outcome [17]. An example question is: ‘Wim chooses surgery and Peter chooses medication. Who is less likely to experience side effects/complications?’ Each answer was either coded as 1 (correct) or 0 (incorrect). Based on Hawley et al. [17], the final measurement was defined as answering both questions correctly (coded 1) versus answering 0 or 1 question correctly (coded 0).

2.2.2. Independent variables

Age was measured as calendar age.

Health Literacy was measured with the 22-item version of the Short Assessment of Health Literacy in Dutch (SAHL-D) [46]. Participants were exposed to multiple choice questions in which they had to select the accurate meaning of health-related words. Each answer was scored 1 (correct) or 0 (incorrect); range 0–22.

Numeracy was measured with an existing scale consisting of three open-ended mathematical questions, such as converting a percentage to a proportion [34]. Again, each answer was coded as 1 (correct) or 0 (incorrect); range 0–3.

Graph literacy was measured with an existing scale consisting of thirteen questions, presenting different types of graphs and questions (nine open-ended and four multiple choice) about understanding the information in the graphs [38]. Each answer was scored 1 (correct) or 0 (incorrect); range 0–13.

2.2.3. Control variables

Two *background characteristics* were measured as control variables, i.e. gender and level of education. Education was divided into low, middle, and high level of education. Low education level ranged from no education to having a degree for the lowest level of secondary education, middle education level included senior general secondary education and pre-university education, high education level was specified by having a higher vocational education or university degree.

In addition, four other *control variables* were measured: prior medical knowledge, medical education, experience with cancer, and experience with hernia. The level of prior medical knowledge and medical education were both measured with one item on a 7-point Likert scale. Experience with cancer/hernia was assessed by asking ‘Have you ever suffered from cancer/hernia? (yes/no). *Moreover, preference was used as a control variable in the experiment.*

2.3. Statistical analysis

Analyses were performed using SPSS version 25. Significance levels were set at $p < .05$. Descriptive statistics were used to describe the sample characteristics and calculate the preference percentages. Chi-square statistics were conducted to investigate differences between younger and older participants in preference for graph format. Differences between experimental conditions in medical knowledge, medical education and experience with hernia were analyzed using ANOVAs. ANOVAs were also conducted to test differences between younger and older participants in verbatim knowledge of the six sets of graph formats. The variable verbatim knowledge was log transformed as the analysis revealed a violation of the assumption of homogeneity of variance. For gist knowledge, these differences were tested using the non-parametric Kruskal-Wallis H test. To examine the role of health literacy, numeracy and graph literacy, we conducted multivariate linear and logistic regression analyses with verbatim knowledge and gist knowledge, respectively, as dependent variables. The following three blocks were entered as separate blocks to be able to see the contribution of each block to the R^2 of the final model: 1) background characteristics (age, gender, education), 2) health literacy, numeracy, and graph literacy; 3) preference for graphical format (control variable) and 4) the six sets of graph formats. We also ran additional models in which interaction terms between the graph formats and age, health literacy, numeracy and graph literacy, respectively, were added, and interaction terms between age and the three literacies. Since adding the interaction terms revealed hardly any significant effects they are not included in the final models, but significant results are described in the text.

3. Results

3.1. Sample characteristics

Due to the stratification strategy, there were no differences in age, gender, and education between the six experimental conditions, and also no differences in gender and education between the younger (<65) and the older (≥65) participants. Mean age was 58.27 (*SD* = 18.00) with a range from 19 to 91 years. There were no significant differences in medical education, medical knowledge and experience with hernia between the six conditions. See Table 1 for background characteristics.

3.2. Preference

Most participants preferred clock (28.7 %), followed by bar (23.1 %) and pie (21.3 %). Table (13.5 %), pictograph (7.6 %) and sparkplug (5.8 %) were least preferred. As illustrated in Table 2, there were hardly any significant differences between the preference of younger and older adults. Only sparkplug was more often preferred by older adults (8.4 %) compared to younger adults (3.2 %; $p < .05$), although it was overall the least preferred format across ages (in the older group together with pictograph).

Table 1
Background characteristics (*N* = 446).

	Older adults			Younger adults			Total		
	n	*M*	*SD*	*n*	*M*	*SD*	*N*	*M*	*SD*
Age	227	72.71[a***]	5.57	219	43.30	13.66	446	58.27	18.00
	n	%		*n*	%		*N*	%	
Gender									
Female	111	48.9		109	49.8		220	49.3	
Male	116	51.1		110	50.2		226	50.7	
Education									
Low	77	33.9		73	33.3		150	33.6	
Middle	74	32.6		73	33.3		147	33.0	
High	76	33.5		73	33.3		149	33.4	

[a]Significant difference between younger and older participants.
*p < .05. ** p < .01. *** p < .001.

Table 2
Preference of older and younger adults for graph format (*N* = 446).

	Older adults		Younger adults		Total	
	n	%	*n*	%	*N*	%
Clock	65	28.6	63	28.8	128	28.7
Bar	54	23.8	49	22.4	103	23.1
Sparkplug	19[a*]	8.4	7	3.2	26	5.8
Table	28	12.3	32	14.6	60	13.5
Pie	42	18.5	53	24.2	95	21.3
Pictograph	19	8.4	15	6.8	34	7.6
Total	227	100	219	100	446	100

[a]Significant difference between younger and older participants.
*p < .05. ** p < .01. *** p < .001.

3.3. Understanding

Overall, table received the highest verbatim knowledge score of all graphs. This format scored significantly higher than clock, pictograph and pie in the total group (all *ps* < .05). In addition, there was a significant difference between older and younger adults on verbatim knowledge, $F(1,442) = 10.18$, $p = .002$. Older adults scored lower on verbatim knowledge than younger adults when they were exposed to clock, $F(1,74) = 7.71$, $p = .007$, or table, $F(1,72) = 5.55$, $p = .021$. Still, table scored highest on verbatim knowledge in the older group. Moreover, within the older group, verbatim knowledge scores on pie were significantly lower ($p < .05$) than those on bar, sparkplug, table and pictograph, but there was no difference between pie and clock. Within the younger group, verbatim knowledge scores on pie were significantly lower than all other formats (see Table 3 and Fig. 2).

Regarding gist knowledge, there were no significant differences between the formats in the total group. However, there was a significant difference in gist knowledge score between the two age groups exposed to clock, $\chi^2(1) = 6.01$, $p = .014$. Older participants in this condition scored lower on gist knowledge than younger participants. On the contrary, a significant difference in favor of the older group was found for table, $\chi^2(1) = 5.56$, $p = .018$. Within the older group, there was a significant difference in gist knowledge scores between the six formats, $\chi^2(5) = 13.88$, $p = .016$, with the largest difference between table and clock in favor of the table, $\chi^2(1) = 3.16$, $p = .076$. Within the younger group, there were no differences in gist knowledge between the graph formats (see Table 3 and Fig. 3).

3.4. The role of age, health literacy, numeracy and graph literacy

The final linear regression model including the potential determinants of verbatim knowledge accounted for 38.0 % of the variance ($p < .001$). Table 4 presents the final model fitted to all variables. A younger age (β = -.11, $p = .010$), and higher levels of graph literacy (β = -.37, $p = .000$) and numeracy (β = -.12, $p = .011$) were predictive of higher verbatim knowledge scores. Furthermore, table was associated with higher verbatim knowledge scores (β = .15, $p = .002$) and pie with lower verbatim knowledge scores (β = .28, $p = .000$). There was only one significant interaction effect, between graph literacy and being exposed to pie (β = .418, $p = .011$), which indicated that verbatim knowledge was lower in participants with higher graph literacy exposed to pie than in those with higher graph literacy exposed to other formats. This difference was not found in participants with lower graph literacy (not in Table).

Table 3
Verbatim and gist knowledge scores by condition (graph formats) and age group.

Verbatim Knowledge	Older Adults			Younger Adults			Total		
	n	*M*	*SD*	*n*	*M*	*SD*	*N*	*M*	*SD*
Clock	38	2.87[a,**]	1.42	38	3.61[b,***]	.86	76	3.24[b,***]	1.22
Bar	35	3.46[b,**]	.89	35	3.66[b,***]	.73	70	3.56[b,***]	.81
Sparkplug	39	3.15[b,*]	1.29	35	3.57[b,***]	.70	74	3.35[b,***]	1.07
Table	37	3.59[a,*,b,***]	.86	37	3.92[b,***]	.36	74	3.76[b,***,c,*,d,*]	.68
Pie	38	2.37	1.36	37	2.43	1.34	75	2.40	1.35
Pictograph	39	3.13[b,*]	1.20	36	3.36[b,***]	1.15	75	3.24[b,***]	1.17
Total	226	3.09[a,**]	1.25	218	3.42	1.02	444	3.25	1.15

Gist Knowledge	Older Adults			Younger Adults			Total		
	n	*M*	*SD*	*n*	*M*	*SD*	*N*	*M*	*SD*
Clock	38	.55[a,**]	.50	38	.82	.39	76	.68	.47
Bar	35	.69	.47	35	.86	.36	70	.77	.42
Sparkplug	39	.77	.43	35	.63	.49	74	.70	.46
Table	37	.92[a,*]	.28	37	.70	.46	74	.81	.39
Pie	38	.74	.45	37	.81	.40	75	.77	.42
Pictograph	39	.77	.43	36	.81	.40	75	.79	.41
Total	226	.74	.44	218	.77	.42	444	.75	.43

Notes: Verbatim knowledge scores were log transformed in the ANOVA analyses.
[a] Significant difference between younger and older participants.
[b] Significant different from pie.
[c] Significant different from clock.
[d] Significant different from pictograph.
[*] p < 05.
[**] p < .01.
[***] p < .001.

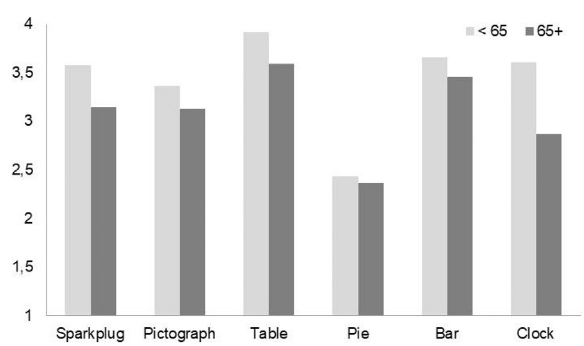

Fig. 2. Mean verbatim knowledge scores of older and younger participants. Graph formats are presented from least preferred (left) to most preferred (right).

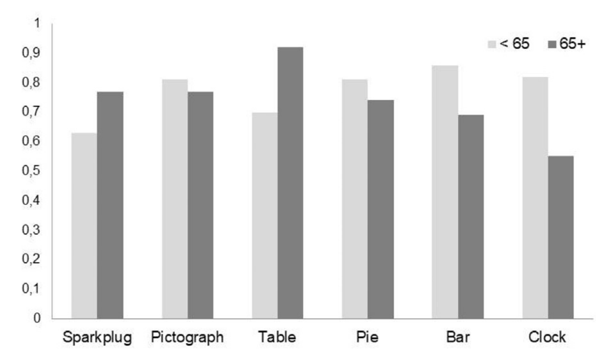

Fig. 3. Mean gist knowledge scores of older and younger participants. Graph formats are presented from least preferred (left) to most preferred (right).

For gist knowledge, only graph literacy (OR = 1.29, p = .000) and health literacy (OR = 1.13, p = .000) were predictive. Table 5 presents the final model. The higher the levels of graph literacy and health literacy, the higher the gist knowledge score (Nagelkerke R-square of the final model: 28.4 %; see Table 5). The only interaction effect that was found was an interaction between age (<65 vs ≥65) and graph format on gist knowledge. Both table (OR = 12.24, p = .009) and sparkplug (OR = 7.51, p = .015) showed an interaction with age in favor of the older age group, who scored for these formats significantly higher on gist knowledge than the younger age group (not in Table).

4. Discussion and conclusion

4.1. Discussion

The first aim of the study was to assess preferences for and understanding of different types of graphs presenting health risk information. Three formats were each preferred by more than one fifth of both older and younger participants: pie, clock and bar. However, pie and clock were not the best formats in terms of understanding. Pie scored lower on verbatim knowledge than all other formats across age groups. This can likely be explained because it was the only format that did not provide any numerical information. Since participants answered the questions with the figures in front of them, they could not read off the answer in this format. Clock was also among the lowest scoring formats across age groups, and yielded lower verbatim and gist knowledge scores in the older group compared to the younger group. In contrast, bar resulted in fairly good verbatim and gist knowledge scores in both age groups. Although bar was well understood in previous studies too (e.g., [17,47]), there was not always a relation between preference and performance (e.g., [36,42,48–50]). The mismatch between people's preferences and their objective performance in risk understanding, in this study found regarding pie and clock, accords with previous research [36,51]. This gives rise to an

Table 4
Final regression model of background characteristics, health literacy, numeracy, graph literacy and graph formats on verbatim knowledge.

	B	SE	Β	*p*-value
Block 1: Background variables				
Age (continuous)	−.001	.001	−.107	**.008****
Gender (0=male; 1=female)	−.012	.020	−.026	.530
Education middle (low = referent)	.040	.022	−.081	.069
Education high (low = referent)	−.011	.023	−.023	.623
Block 2: Graph Literacy, Numeracy and Health Literacy				
Health Literacy	.004	.002	.074	.094
Numeracy	.024	.009	.116	**.011***
Graph Literacy	0.33	.004	.374	**.000*****
Block 3: Control variable				
Preference	.016	.03	.025	.524
Block 4: Graph formats				
Bar	.049	.031	.076	.112
Sparkplug	−.002	.031	−.003	.955
Table	.084	.030	.134	**.006****
Pie	−.183	.030	−.294	**.000*****
Pictograph	−.009	.030	−.014	.775

Notes. Verbatim knowledge was log transformed. Clock served as reference category for the graph formats. Final verbatim knowledge model: $F(14, 429) = 20.381$, $p < .001$; Adjusted R^2 final model = .381. Block 1: ΔR^2 = .065, p = .000; Block 2: ΔR^2 = .202, p = .000; Block 3: ΔR^2 = .004, p = .106; Block 4: ΔR^2 = .128, p = 000.

Table 5
Final regression model of background characteristics, health literacy, numeracy, graph literacy and graph formats on gist knowledge.

	B	SE	OR	[95 % CI]	*p*-value
Block 1: Background variables					
Age	−.002	.007	.998	[.983, 1.012]	.744
Gender (0=male; 1=female)	−.388	.285	.678	[.388, 1.185]	.173
Education middle (low = referent)	.020	.303	1.020	[.563, 1.849]	.947
Education high (low = referent)	−.053	.336	.948	[.491, 1.830]	.874
Block 2: Graph Literacy, Numeracy and Health Literacy					
Health Literacy	.122	.032	1.129	[1.060, 1.203]	**.000*****
Numeracy	.236	.132	1.266	[.978, 1.641]	.074
Graph Literacy	.257	.055	1.293	[1.162, 1.440]	**.000*****
Block 3: Control variable					
Preference	−.139	.359	.870	[.431, 1.758]	.698
Block 4: Graph formats					
Bar	.534	.428	1.707	[.737, 3.950]	.212
Sparkplug	−.014	.405	.986	[.446, 2.182]	.973
Table	.667	.432	1.949	[.835, 4.545]	.123
Pie	.629	.419	1.875	[.825, 4.263]	.134
Pictograph	.797	.436	2.220	[.945, 5.213]	.067

Notes. Nagelkerke R^2 = .284. Block 1: Nagelkerke R^2 = .042, p = .013; Block 2: Nagelkerke R^2 = .265, p = .000; Block 3: Nagelkerke R^2 = .265, p = .748; Block 4: Nagelkerke R^2 = .284, p = .231.

interesting dilemma: should we design graphs in patient decision aids in ways that people tend to prefer, and may thus be more motivated to look at, or should we make design choices based on demonstrated effectiveness such as understanding [52]? In our opinion, preference for one form of graph does not mean disinterest in other forms that are more effective. In line with this, it has been recommended to not rely solely on people's preferences and opinions about visual cues [36]. However, satisfaction is important for information processing of older adults because it increases their motivation for uptake of information [53,54]. Cognitive illustrations, i.e., illustrations that visually represent text to facilitate comprehension and learning of information, have indeed been found to improve older adults' satisfaction as compared to text only [53,54], and they can also improve recall in older adults [54]. It can therefore be strived for to develop graphs that are both perceived as appealing (i.e., can contribute to satisfaction with the information) and are well understood. Combined, almost half (49.0 %) of the participants preferred the 'circular formats' of pie or the clock, which are similar graphs. This is much higher than the 23.1 % who chose the next preferred format of bar. However, pie and clock scored low on understanding. Therefore, bar seems to score best in the balance between preference and understanding. In line with our results, preferences for bar charts were also found in previous studies [e.g.,19,42,48,51], in particular when multiple risks were compared [47]. Also in a recent study on optimizing graphical displays of longitudinal medication adherence data, a slight majority of patients, in particular those with higher health literacy, and nearly all clinicians preferred the bar graph [55]. In a study among patients with low numeracy and graph literacy bar charts, although most preferred, resulted in lower comprehension as compared to tables and line charts [42]. In another study among older adults bar charts, again the most preferred format, resulted in lower memory as compared to stacked bar charts [51]. Line charts and stacked bar charts were not included in the current study, but table, although not often (13.5 %) preferred in our study, indeed yielded high knowledge scores. Gist knowledge of table was even higher in the older group than in the younger group. Since the graphs were displayed while participants answered the questions, the high scores on understanding might be explained because the answer could be read without the need to match colors, numbers and legend. Regarding preference, the other graphs, in particular pie and clock, were more colorful than the table, which might explain why the table was perceived as visually less appealing. However, in previous research using the same formats as in the current study, the table was rated as the most effective, trustworthy and scientific compared to the other formats [17]. Therefore, this format seems to have potential (see also 4.2).

The second aim of the study was to examine the contribution of health literacy, numeracy and graph literacy in understanding of the graphs. Lower age, higher numeracy and higher graph literacy contributed to higher verbatim knowledge scores, whereas for gist knowledge, higher health literacy and graph literacy resulted in higher scores. Thus, adequate graph literacy is important for both verbatim and gist knowledge. The results confirm findings from previous research that graphical risk information might not automatically be useful for people low in graph literacy [39]. According to Cokely et al. [56] nearly anyone has the ability to make well-informed and skilled decisions as long as they understand risks. In particular gist knowledge is associated with improved decision making [17,26,27]. However, static visual aids seem particularly helpful for people with low numeracy as long as they tend to have moderate-to-high graph literacy [36]. Thus, it is important to find strategies that also can support those low in graph literacy. Table, a format which is not typically a graph, might be a useful format for this group, in particular when a textual summary of key numerical information is included (see also 4.2).

A limitation of this study is that we measured verbatim and gist knowledge with the same numerator size for each of the six types of graphs. Previous research indicates that some types of formats, e.g. bar charts, are better understood for more common outcomes and/or for larger numerators (>10/100 or >100/1000), while others, e.g. pictographs, are processed more quickly and better understood when the numeric risks are <10/100 or <100/1000 [39,48]. Although in our study bar performed not worse than pictograph despite the risks of <10/100, future research could address this limitation by replicating the current study with different levels of risks of side effects or complications. Other limitations of our study include that the survey was only disseminated to Dutch-speaking people, recruited by a panel, and completed online. This could have caused recruitment bias. Moreover, participants were provided with a hypothetical scenario, which does not replicate decisions by people actually facing the hernia decision taking place in clinical practice [57]. Furthermore, the graphs of the two hernia treatments showed different possible risks of side effects and complications. In these graphs the same color was used for risks with different severity. For instance, the red colored outcomes from medication was a list of six different side effects (e.g., headache, dizziness), while the red color in the surgery graph only represented one complication (i.e., infection of the wound) that might be considered more serious than any of the risks under medication. This could be difficult for the participants to comprehend and might have affected the outcomes on understanding. There is a lot of variation between studies investigating preference and understanding of graphs presenting risk information, not only in the design of the graphs, but also in the design of the study, including the sample composition and the way of measuring preference and understanding. This complicates the comparison of outcomes and explanation of differences in results. An important strength of the current study is that we included a well-balanced sample that ensured equal representation of age, gender and education in the different experimental conditions, while measuring participants' health literacy, numeracy and graph literacy levels. Future research could replicate this with different types of graphs and measurements to further deepen our insights.

4.2. Practical implications

Table was well understood but not often preferred. Therefore, to increase motivation to process the information, a combination of cognitive (e.g., table) and affective visual cues could be considered, for instance an illustration or photograph that aims to evoke a positive feeling. Affective cues are irrelevant for understanding, but have value in improving satisfaction with information in older people [54]. Since being more (emotionally) satisfied leads to greater recall of information of older adults [53], the combination of both types of visual cues might be effective for this group. Affective cues can be added to decision aids as separate illustrations next to graphs, but they can also be embedded in the graphs to provide meaning to the information presented. For example, Peter and colleagues [58] added affective categories, i.e. affective labels that placed the information into categories of poor, fair, good, or excellent, to health plan information presented in a bar chart format. These affective cues supported people in integrating important quality information into their judgments [58]. Fraenkel et al. [57] found that adding both a graphic representation as well as conceptual illustrations to numerical information decreased risk perceptions and increased likelihood of starting a treatment for rare (2%) risks, but only among participants with lower education. This indicates that patients with higher levels of education may be less responsive to visual aids than those with lower education. Similar to risk perceptions, understanding might also be improved by adding explanatory content such as labels or textual information describing the numerical information depicted in graphs [36,59]. In this regard, text difficulty should be taken into account as well. Non-difficult texts have been found to be beneficial (e.g., improved recall) for older people with low health literacy without added value of visual cues [60]. Visual cues particularly improved information processing if the textual information could not be further simplified [60]. Furthermore, since people with low graph literacy misinterpret graphs more frequently than people with high graph literacy, all features, including spatial (e.g., the height of graphs) and conventional (e.g., axes labels and scales) ones should convey the same meaning to help less graph literate individuals to reach the correct interpretation [61].

4.3. Conclusion

Simple and familiar design formats are often preferred for receiving health risk information, but these formats do not necessarily improve understanding [12]. Two of the most often preferred formats, pie and clock, can be considered as 'simple and familiar' but were not understood well. Bar charts were among the most preferred formats, and resulted in fairly good knowledge scores in both younger and older people. Although tables were less often preferred, this format was well understood, even better in older than in younger adults, possibly because it summarizes key statistical information in a less graphical way. The results can be used in the development of interventions to communicate risk information to vulnerable groups. Because graph literacy skills appeared to be essential for both verbatim and gist knowledge, these skills need to be taken into account when designing graphical risk information.

Contributors

JW designed the study, conducted the analysis, wrote the manuscript, and is the guarantor. MA conducted data collection, helped writing the manuscript and revised the manuscript. LD and JJ helped design the study, and revised the manuscript. All authors take responsibility for the integrity of the data and the accuracy of the data analysis. All authors approved the final version of the manuscript.

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CRediT authorship contribution statement

Julia C.M. van Weert: Conceptualization, Methodology, Formal analysis, Data curation, Writing - original draft, Funding acquisition. **Monique C. Alblas:** Software, Investigation, Resources, Writing - review & editing, Visualization. **Liset van Dijk:** Conceptualization, Writing - review & editing. **Jesse Jansen:** Conceptualization, Methodology, Writing - review & editing.

Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.pec.2020.06.031.

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