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Data display format and hospital ward reports: effects of different presentations on data interpretation

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Background: Graphs are often used in medical communication, both in clinical practice and health management. They can help the processing of quantitative information but may also contribute to drawing wrong conclusions. The aim of the survey is to study the graphical perception of the data at the management level and its possible effects, showing how some criteria of appraisal of a phenomenon are influenced by the graphical format. **Methods:** One hundred and five medical doctors and health direction professionals of hospitals in Naples, Rome, Siena and Turin were interviewed. Four different graphs or table related to the same hypothetical data on average hospital stay in the period January 2000 to September 2003 were shown to participants, and their impressions were recorded. **Results:** Less than one-fourth of the participants understood that the data set was the same for the different diagrams. The process of understanding is mostly correlated with being a director, having a degree in medicine and working in central–northern cities. The table seems easier for interpretation (98.1%), more suitable (84.8%), more used (92.4%) and more pleasant than other data presentation. On the other hand radar format had worse results in all questions. **Conclusions:** The choice of a graphical format may influence the understanding of data. Further research is needed in order to sustain the improvement of medical and health professionals' knowledge in the display data format.

Introduction

Graphic representation is a fundamental tool used to summarize and describe all types of data. The way in which information is presented influences data interpretation and consequent decision-making.¹ According to Marshall McLuhan of the Toronto's Communication School, 'the Medium is the Message'.² In 1967, with this provocative slogan, the Canadian sociologist opened a new frontier in communication, based on the study of the Medium: the nature of Medium is more important than the contents that it spreads, and reader's sensitivity to message is influenced by Medium's familiarity and appeal.³

In order to investigate this phenomenon in the medical field, a prospective study was conducted in an American Hospital by Elting and colleagues in 1999, examining the effect of the method of data display on physician investigators' decisions. The study showed that accuracy of decisions was affected by the type of data display and positive or negative framing of data.⁴

Recently, scientific literature has highlighted the importance of health numeracy, defined 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'.⁵

According to this background, we published a pilot study in 2006, designed to estimate the feasibility of a survey on graphical perception of data and its possible effects on health management in the Italian setting, showing that some criteria of appraisal of a phenomenon are influenced by graphical format of data representation.⁶

Given these results and in order to further elucidate this phenomenon, we conducted a multicenter survey in Italy.

The specific aims of the study were as follows:

- does the data display format influence the interpretation of results in some way?⁷

- is the participant aware that the four diagrams represent the same data which belonged to a single ward? and
- is the participant able to assess the graphs showed correctly?

Methods

Study population and sampling procedure

A cross-sectional survey involving randomly selected participants was carried out in five Italian Hospitals in the provinces of Naples, Rome, Siena and Turin.

The sample size calculation was based on the following parameters:

- population size (hospital doctors): 17 000 in the four regions (Piedmont, Tuscany, Lazio and Campania);
- expected frequency of the main result (suspect that graphs were coming from the same data set): 25%; and
- worst acceptable result (worst expected case frequency): 15%.

Given these parameters, we calculated a sample size of 72 subjects (medical doctors) (95% confidence level). We were able to recruit 88 medical doctors and other personnel with managerial tasks in the same hospitals, summing up to 105 health managers with different seniorities (<5 and >20 years of service) and roles. The sampled population characteristics are presented in table 1.

Questionnaire and interview

Every subject saw four different data display format concerning the average stay in the hospital and the total amount of hypothetical admissions from January 2000 until September 2003. Therefore, participants were administered a questionnaire, which was previously validated in the pilot study,⁷ and divided into two parts: in the first section personal data, education, seniority, speciality and employee were described; while the second questioned opinions concerning different data display

Table 1 Characteristics of all study participants

Variable	Number (Mean %)
Region	
Campania	36 (34.2)
Lazio	33 (31.4)
Piedmont	15 (14.3)
Tuscany	21 (20)
Mean age (standard deviation)	48.2 (8.7)
Gender	
Females	28 (26.7)
Males	77 (73.3)
Type of degree	
Medicine	88 (83.8)
Economics/law/political sciences	8 (7.7)
Other	9 (8.5)
Work position	
Director	14 (13.3)
Responsible of complex structure	26 (24.8)
Responsible of simple structure	20 (19)
Medical director	38 (36.2)
Company secretary	7 (6.7)
Years of work	
≤5	29 (27.6)
6–15	31 (29.5)
>15	45

formats. It is important to underline that the four diagrams represented the same data that belonged to a single ward.

The four types of display used were: bar graph; radar; table; linear wave graph (figure 1):

Bar graph: well-known diagram, of immediate and familiar reading.

Radar: unusual diagram, almost unknown, but useful for representing a cyclical temporal series. This type of graph, a form of radial graphing, is considered of great utility in the presentation of health-related research.⁸ In order to represent different years, coloured lines with various shadings of the same colour were used.

Table: very familiar graphic representation. The table showed annual data about permanence average in hospital and total amount of admissions.

Linear wave graph: it was obtained by smoothing a broken linear graph, for an easy and immediate reading of the variables trend.

Diagrams were constructed using two colours: black for reference system, and blue for represented data.

Some explanations were given to the sample population before showing the four data display formats:

- (1) represented data, concerning the average duration of the stay in the hospital and the total number of admissions from January 2000 until September 2003, was shown to responders as belonging to four different units (A, B, C and D);
- (2) the number of beds was the same for all units and, in the considered time period, the units did not modify the staff nor the technologies used; and
- (3) the graphical format used in order to describe the data was different among units.

After supplying this information, participants were introduced to the four types of diagrams and the relative judgements to the readability, the familiarity, the annoyance, etc were collected. Moreover, based on the data described in the diagram, a judgement on the unit was asked in relation to the variable represented (average stay in hospital and number of shelters) with a series of closed-ended answers: great improvement, light improvement, constant, light worsening, great worsening. Subsequently, the questionnaire asked to express a judgement with respect to diagram adequacy, unpleasantness and difficulty in understanding, by using a scale from 0 to 10. Finally, participants were asked to state which graph they perceived as being the best and why. In order to verify the coherence of the answers, the judgements of unpleasantness and

difficulty in understanding, in contrast, with pleasantness and easiness in understanding were inverted during the phase of data analysis.

Statistical analysis

We calculated frequency tables with absolute numbers, percentage, mean and standard deviation. Differences between groups were assessed by using the Mann–Whitney test and chi-square test (Fisher's test where suitable) for quantitative and qualitative variables, respectively.

A logistic multivariate regression was used in order to find variables associated with the thought that tables and figures concerned the same situation. In this analysis, a step-wise (backward elimination) approach was used, using the following as starting covariates: age, gender, type of degree (medicine vs. others), position (directors vs. others), macro-region (North-Central: Province of Turin, Siena and Rome; Southern: Province of Naples) and year of work seniorship (under vs. over 15 years). The statistical significance was set at $P \leq 0.05$.

The statistical package used was SPSS, release 12.0.

Results

A total of 105 responders entered the study (response rate 100%) with a mean age of 48.2 years. Table 1 shows some characteristics of the participants. Most of the participants have a Medical degree (88), are males (77 vs. 28 females) and the mean (SD) of years of work is 9.7.

A total of 22.9% of the interviewers suspected that graphs were coming from the same data set. Table 2 shows the associations between positive answers and Region of residence ($P=0.021$) and years of work ($P=0.013$). Specifically, the number of participants who were aware that the same data set was used, is different according to the Region of residence: 41.7% of Northern–Central Italy and 9.1% of Southern Italy; 42.9% of health professional in directorial position and 19.8% of health professionals in other positions recognized that graphs came from the same data set.

The multivariate analysis (table 3) revealed that the following variables are associated with the thought that tables and figures concerned the same situation: being a director (OR=4.53; 95% CI 1.02–20.14), having a degree in Medicine (OR=11.77; 95% CI 1.23–112.37) and working in Northern–Central cities (OR=4.44; 95% CI 1.18–16.67).

Among the sample population that expressed a judgement, the percentage of correct assessment (to be more accurate the one judging the unit in 'slight worsening') resulted higher with linear graph, table and bar graph (41.9% and 42.9% and 39% correct judgement, respectively) in comparison with radar plot (24.8%). The table is the data representation format that is used more often (92.4%); the 62.9%, 40% and 3.8% of responders utilize the bar graph, the linear wave graph and the radar, respectively (3.8%). The table was chosen as the preferred format (31.4%), followed by the bar graph (23.8%), the linear wave graph (21.9%) and the radar plot (3.8%). One-third of the responders declared that they needed more data before giving an opinion concerning units trend (32.4% for bar graph; 34.3% for table; 31.5% for linear graph). When analysing the radar plot, 61% declare the necessity of more data (Supplementary figure S2).

The most suitable presentation of data appeared to be the table (84.8%), then the linear wave graph (73.3%) and the graph bar (61%). Only 34.3% of the responders considered the radar suitable.

The table turns out to render the data presentation the least unpleasant (95.2%), followed by the linear graph (80%), the bar graph 61%, and the radar which is the least preferred with 54.3%.

Almost all of the responders (98.1%) consider the table format to be easier to interpret, compared with the linear graph (84.8%) and the bar graph (83.8%), while the radar is judged not difficult to understand by 24.8% of the responders (Supplementary figure S3).

Discussion

In the health sector, the graphical representation of data could be applied in different fields, such as research, management and clinical decision-making.

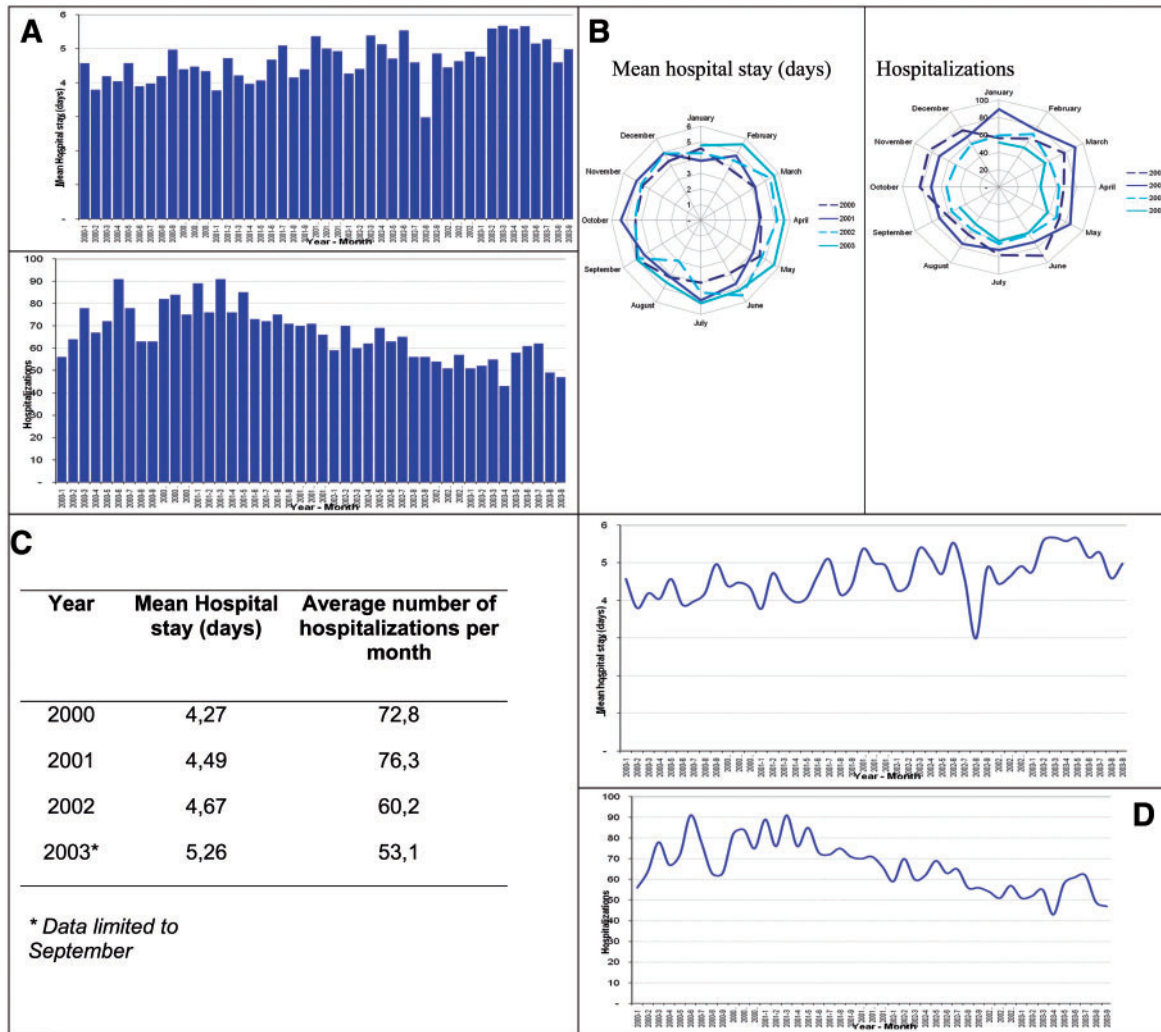


Figure 1 The graphical format showed: (A) bar chart; (B) radar; (C) table; (D) linear plot

Table 2 Association between the thought that graphs coming from the same data set and different socio-demographic characteristics

Variable	Yes (%)	No (%)	P*
Region			
Northern–Central Italy	21 (41.7)	48 (58.3)	0.021
Southern Italy	3 (9.1)	33 (90.9)	
Age	47.29 (8.5)	48.48 (8.7)	0.557**
Gender			
Females	5 (17.9)	23 (82.1)	0.462
Males	19 (24.7)	58 (75.3)	
Type of degree			
Medicine	23 (26.1)	65 (73.9)	0.111
Other	1 (5.9)	16 (94.1)	
Position			
Directors	6 (42.9)	8 (57.1)	0.056
Others	18 (19.8)	73 (80.2)	
Years of work			
≤15	19 (31.7)	41 (68.3)	0.013
>15	5 (11.1)	40 (88.9)	

*P-value of χ^2 test

**P-value of Mann–Whitney test

Table 3 Variables associated to the thought that graphs coming from the same data set

Variable	Crude OR (95% CI)	Adjusted OR ^a (95% CI)
Region		
Northern–Central Italy	4.81 (1.33–17.54)	4.44 (1.18–16.67)
Southern Italy (reference)	1	1
Age	0.984 (0.934–1.037)	NS
Gender		
Females (reference)	1	NS
Males	1.51 (0.50–4.51)	
Type of degree		
Medicine	5.65 (0.71–45.06)	11.77 (1.23–112.37)
Other (reference)	1	1
Position		
Directors	3.04 (0.94–9.87)	4.53 (1.02–20.14)
Others (reference)	1	1
Years of work		
≤15	3.71 (1.26–10.89)	NS
>15 (reference)	1	

a: derived from the multivariate analysis

NS: not significant

The research from Elting *et al.*⁴ shows how the data display format could have a great influence on physician investigators' decisions to stop hypothetical clinical trials. The pie charts and bar graphs seemed to be less well understood than table and icon displays. Icon displays led to

superior decisions by participants at all levels of experience, but they were not liked by the participants.

A British study used a randomized controlled trial design to investigate the effects of two forms of data presentation—league tables and control

charts—on health service decision makers; the participants preferred using control charts (a graph) rather than league tables but the response rate was very low.⁹ Moreover, as pointed out by Colligan and colleagues,¹⁰ the layout of a process map can have a deep influence on the perception of quality and safety problems, so it should be considered with care the possibility to use more than one map to ensure that different aspects of certain phenomena are fully understood.

A lot of literature focuses on the graph communication with patients and methods designed to improve this area.

In Brundage *et al.*¹¹ formats generally preferred by cancer patients for presenting health-related quality of life (HRQL) and where data are interpreted most accurately results a simple linear representation of group mean HRQL scores.

In Pylar and colleagues, the goal was to assess the patients' interpretations of graphical information presented in a videotape for decision aids in benign prostatic hyperplasia treatment. Patients were more accurate in their interpretations of information for simpler graph formats (pictograph) and less accurate for more complex graph formats (bar graph). Differences in accuracy were also systematically associated with level of education.¹²

A recent paper on health numeracy highlights the fundamental role of obtaining, interpreting and processing quantitative information for health behaviour and decisions.⁵

The famous case of misrepresentation in the 1998 Lancet graph, who led to a crisis in confidence about the MMR vaccine, showed the scientific world that there are lessons to be learned in order to avoid big mistakes.¹³ However, there is still a lack, especially in medical formation, of a specific education about display formats and this can render the health-care system and patient safety unsure.^{14,15}

In the present study, less than one-fourth of the participants understood that the data set was the same in the different diagrams. This understanding is correlated positively with being a director, having a degree in medicine and working in central–northern cities. When taking into consideration, the participants who expressed a judgement, the higher correct judgement referred to the linear graph and table format (41.9% and 42.9%). The table seems to be easier to interpret (98.1%), more suitable (84.8%), more used (92.4%) and more pleasant compared with other data presentation. On the other hand, radar format had worse results in all questions.

The results of this study show how there is a strong need of improving the comprehension of tables and graphs within the health-care system, in order to improve informed medical decision-making in the hospital medical management.

This study has some limitation that needs to be considered with care when interpreting the results. First of all, given the cross-sectional nature of the results, the interpretation of the impact of graphical format is restricted. Moreover, some of the variables actually used for the explanation of the differences between groups are actually at the same time confounding the research, even if the use of a multivariate approach should have lead to avoid this bias. Future research on this topic should use more efficiently a prospective design in order to gain better level of knowledge in this field.

In conclusion, we are completely in agreement with Gigerenzer *et al.*¹⁶ who, in a recent monograph, suggest that medical and statistical educators need to consider ways to increase the ability of future health professionals to comprehend statistical methodology, which should exceed the knowledge that is currently conveyed in introductory

courses. One of the first steps of this education must be the improvement of the data communication with display formats.

Conflicts of interest: None declared.

Key points

- The choice of a graphical format may influence the understanding of data in the hospital–medical management.
- The misinterpretation of data display format could have an impact on health decision making.
- Medical and statistical educators need to consider how to make future health professionals able to comprehend statistical methodology that exceeds what is currently presented in introductory courses.

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