GRAPHICAL STATISTICS AS AN OPTION FOR THE IMPROVEMENT OF LEARNING IN PSYCHOLOGY

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Many students have difficulties in the appreciation of concepts related to statistical problems. Various researches have determined how students' aptitude to solve statistical proofs can be affected by the methods of displaying data. The application of distinct visual aids could improve statistical reasoning, sustaining the principle of graphical facilitation. Some authors did not agree with this point of view, highlighting the complications related to the use of illustrations; they upheld that visual aids could burden the cognitive system with unserviceable information. We confront the basic level of statistical reasoning on probabilities regarding two methods of problem arrangement: verbal-numerical and graphical. Students in Spain and Italy solved the homolog and paired problems in a verbal-numerical and graphical way, in different sequences. Analysis of the correctness of responses and the reasoning applied, managed to compare these ways of presentation and to clarify the cognitive process applied in the problem solving.

INTRODUCTION

A large number of studies have been carried out to evaluate the influences on problem solving produced by the general characteristics of the issue. Research conducted on the role played by 'problem organisation' in the selection of solving strategies deserves further attention in order to understand why and how individuals are often affected by biases when reaching a solution. By the way, probabilistic statistical problems are a particular type of enigma that people are daily requested to solve. In particular, the Psychology undergraduates frequently show great difficulties in understanding statistical concepts and in learning statistics (e.g., Guàrdia et al., 2006). This fact implies a complex interaction among many factors: previous scholastic experiences and performances (e.g. Guàrdia et al, 2006), beliefs and attitudes towards statistics (e.g., Garfield & Gal, 1999) and emotional aspects (e.g., Chiesi, Primi & Carmona, 2011).

Some authors affirm that the application of some visual aids could be a capital way for enlightening statistical reasoning (e.g., Brase, 2009). In contrast, others (e.g., Knauff & Johnson-Laird, 2002) sustain that illustrations could inhibit reasoning in dilemmas, because they could burden the cognitive system with supplementary evidences, beside the point. Also delMas, Garfield and Ooms (2005) highlighted the difficulties implied in student's interpretation of various graphical representations.

Several researchers tried to delve into the characteristics of probabilistic statistical reasoning, in order to interpret the faults in data comprehension with and without illustrations. They suggested that this reasoning moves above hierarchical steps; in particular Polaki (2005) outlined a remarkable framework that defined the progress from subjective to numerical probabilistic reasoning.

In this theoretical context, the goal of this research is to investigate whether graphical representations can facilitate or impede the probabilistic statistical reasoning in psychology undergraduates. For this reason we evaluated the subject's performance in solving two parallel formats of problems: verbal numerical and graphical. We identified some factors that could affect the student's performance; among the external factors, we considered the problem presentation format; and as internal factors, we recognised abilities (numerical and visuospatial) and personal aspects (attitudes towards statistics and statistical anxiety). We aimed also at examining and comparing the specific cognitive procedures of probabilistic statistical reasoning applied in the solution in these two formats. We could deem, indeed, that different formats of the same problems could promote different levels of probabilistic reasoning.

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METHOD

Participants

Participants consisted of 442 undergraduates in Psychology, attending the first year of the degree course at the University of Barcelona (Spain) (n=155), University of Cagliari (Italy) (n=64), University of Genoa (Italy) (n =129) and University of Trieste (Italy) (n=92). The average age of the participants was 20.6 years (sd = 5.4). The group consisted of 327 females (74.7 %). We decided to exclude students that declared to have studied statistics as part of their curricula (n= 53). Data collection took place from September to October 2013. The sample involved students who voluntarily participated in the research. The sampling was non probabilistic; in order to engage the participants, we contacted the lecturers for the Psychology degree in each University; then they gave the evaluations instruments to their students.

Instruments and Procedure

We submitted the instruments, in papery form, to a large group in a lecture room; each group in every country compiled the problems in their native language.

In order to inquire probabilistic statistical reasoning, according to a series of pilot studies (e.g., Agus et al., 2013; Penna et al., 2014), we created measures composed of five pairs of analogous problems in two formats of arrangement (Format N – verbal numerical – and Format G – graphical). By this, we can match, for the same subject, the reasoning offered, arranged in parallel dilemmas. The problems are presented in different orders (numerical-graphical - NG - and vice versa - GN) and sequences. We chose to investigate the reasoning in “naïve” students, deprived of statistical abilities, in order to estimate the genuine impact of the format on the solution. We assessed statistical reasoning for probabilities, with mention to elementary mathematical skills achieved at secondary school. Each problem had a brief exposure and then four closed questions (only one was correct). Formerly the person was requested to explain the reasoning applied, in an open question, and we coded the open answers by applying Polaki’s framework (2005) to individuate the level of probabilistic reasoning.

In order to evaluate the numerical and visuo-spatial prerequisites, we applied two scales of the Intermediate Form of Primary Mental Abilities (P.M.A.) (Thurstone & Thurstone, 1981a, b). Also we applied the Survey of Attitudes Towards Statistics (SATS-28) (Schau, Stevens, Dauphine, & Del Vecchio, 1995). Then the students compiled the Statistical Anxiety Scale (SAS) (Colet, Seva, & Condon, 2008). Both SATS-28 and SAS demonstrated the cross-country validity between an Italian sample and a comparison Spanish sample.

We used the statistical software EQS 6.1. We computed the Confirmative Factor Analysis for each group of items on probabilistic reasoning. Then we applied a mixed-design Ancova, in order to evaluate the existence of ‘graphical facilitation’. To compare the levels of reasoning applied in two formats, we performed also a non-parametric Wilcoxon’s Test on the classifications.

DATA ANALYSIS

We evaluated the descriptive statistics in relation to the answers given to each pair of items. Then we chose to apply two separate CFAs in relation to each group of items inquiring the probabilistic statistical reasoning, in verbal numerical (FN) and then in graphical format (FG). The observed variables showed distributions with the non-symmetrical curve and the non-normal multivariate distribution; for these reason the Elliptical Least Square Solution (ELS) was applied. All five items in both formats appeared useful to evaluate each dimension inquired (Table 1). On the bases of the estimation of the fits in two formats, we decided to evaluate the total number of correct responses in relation to each dimension. We observed a lower mean in the verbal numerical format (m= 2.21, ds=1.53) than in graphical format (m=2.85, ds= 1.37).

In order to compare the correct responses in two parallel formats, we applied a mixed-design Ancova, when the responses in the two formats were repeated measures, evaluated in relation to two between factors: *order of problem presentation* (NG / GN) and *country* (Spain and Italy). We used the scales of prerequisites (numerical and visuo-spatial) as covariates, previous academic records (marks awarded for university admission), attitudes towards statistics and statistical anxiety. We observed a significative effect of covariates for the interaction between *format*numerical abilities* ($F_{(1;348)}$=8.792 p=.003). We then obtained a significant effect of *format*order of problem presentation* ($F_{(1;348)}$=20.733 p=.0001). By this we observed that the number of correct responses is generally higher in the graphical format than in the verbal numerical, but this number decreases when the students solve the graphical problems at the first step. Conversely the correct solutions in verbal numerical format increases when they solve these N problems at the second step.

Table 1 – CFA (ELS) Goodness of Fit indices

CFA Analysis (Total sample n= 389)	χ^2 (df) p	FACTORIAL LOAD	CFI	RMSEA (90% CI)	AGFI	SRMR	CRONBACH'S α
NF Verbal numerical format	12.161 (5) p=.032	from .37 to .57	.974	.061 (.016-.105)	.970	.031	.608
GF Graphical format	16.747 (5) p=.005	from .29 to .58	.938	.078 (.039-.120)	.953	.041	.566

Legend: CFI= Comparative Fit Index; RMSEA (90% CI)= Root Mean Square Error of Approximation with Confidence Interval; AGFI= Adjusted Goodness of Fit; SRMR= Standardised Root Mean Square Residual; CRONBACH'S ALPHA= Cronbach's α Reliability Index

With the intention of exploring the peculiarities of probabilistic reasoning we categorised the answers presented in the open questions, inquiring the cognitive process used to individuate the adequate solution for each pair of problem. Polaki (2005) articulated an outline to detect the stages of probabilistic statistical reasoning: level 1 (subjective reasoning: students ignore given numerical data in assessing the problem); level 2 (transitional reasoning: the application of numbers is inappropriate); level 3 (informal quantitative reasoning: learners keep track of the complete structure of the problem but they do not connect all portions of the problem); level 4 (numerical reasoning: students allocate correct numerical values).

Two independent raters applied Polaki's framework (2005). We calculated the inter-raters agreement by applying Cohen's Kappa coefficient. The values of agreement range from a minimum of .718 to a maximum of .899. Then we related the reasoning in each homologous pair of problems. Considering the classifications as ordinal variables, we calculated the Spearman's Rho to appraise the co-graduation between the levels of probabilistic reasoning in two formats. Formerly we computed the non-parametric Wilcoxon's Test, to measure the dissimilarities between the categorisations in each pair. We could note a direct and significant co-graduation between all pairs of problems. We detected also a significant difference in the pairs A1-B4, A2-B1, A3-B3 and A4-B2, when the subjects applied a higher level of probabilistic reasoning in verbal numerical format ($p<.05$). But we observed an opposite trend in the pair A5-B5 because the student applied the higher level of probabilistic reasoning in the G format ($p<.05$).

CONCLUSIONS

This research aimed at understanding if the graphical statistic could be an efficient method to overcome the difficulties endured by the Psychology undergraduates in Statistics. The comparison between the probabilistic homologous problems in verbal numerical and graphical format highlighted how graphical problems allowed the same inexperienced students to reach a higher number of correct responses. These facts were evaluated controlling the effect of abilities, attitudes towards statistics and emotional aspects (e.g., Garfield & Gal, 1999; Guàrdia et al., 2006). Coherently with the bibliography, a significant positive role is assumed by the numerical ability. But the effect of the order of problem presentation (NG/GN) is worthy of attention; we observed a general effect of 'graphical facilitation' that is reduced moreover when the graphical problems are solved as a first step. On the other hand, the number of correct solutions in verbal numerical format increased when these problems were presented at the second step. These results could be related with the 'familiarisation' of subjects with the structure of problems amplifying the effect of 'graphical facilitation' and that improving also the solution in verbal numerical format. These facts suggested the relevance of knowledge of the problem structure in facilitating the correct problem solving in both formats and the utility of switching to different problem presentation formats in order to improve the performance (e.g., Gibbs, 2006).

In relation to the comparison of the level of probabilistic statistical reasoning applied (Polaki, 2005), it would seem that we had generally a higher level of probabilistic reasoning in the verbal numerical format. These facts are important because these students didn't have a statistical education, but were 'naïve' in relation to statistical knowledge. Therefore these outcomes would be related also to the specific habits, common in European and Western countries, to teach and learn by the classical verbal numerical approach, discarding the graphical ways to explore the information. Moreover these results could support in a new way the concept of the individual-task combination (Zhu & Gigerenzer, 2006), that highlighted as the reasoning and learning could be considered the resultant of the multifactorial interaction among many aspects (the structure of tasks and the individual specificity). At that point, the usefulness of graphical statistics could be exploited if abilities, knowledge and preliminary requisites are precisely considered. The assessment of subjects' features seems to be advantageous for the enhancement of statistical reasoning, also in relation to the application of graphical methods.

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