

STATISTICAL LITERACY SURVEY ANALYSIS: READING GRAPHS AND TABLES OF RATES AND PERCENTAGES

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In 2002, an international survey on reading graphs and tables of rates and percentages was conducted by the W. M. Keck Statistical Literacy Project. Respondents included US college students, college teachers worldwide and professional data analysts in the US and in South Africa. The survey focused on reading informal statistics – rates and percentages in tables and graphs. Some high error rates were encountered. In reading a 100% row table, 44% of students misread a description of a single percentage. In reading a pie chart, 53% of data analysts misread a comparison of two slices. In reading an X-Y plot, 81% of college teachers misread a “times more than” comparison. When asked if a Simpson’s Paradox reversal was possible in an observational study, almost half of each group – students, data analysts and college teachers – disagreed. But helping students learn these skills takes considerable time. A new on-line tool has been developed to help students practice using ordinary English to describe and compare rates and percentages. This tool decreased the class time necessary to teach this skill and helped make it possible to teach statistical literacy online. Statistical educators now have both the rules and the tools to teach students how to read and interpret summary data. To avoid being charged with educational negligence, statistical educators should accept responsibility for establishing the grammatical rules for writing ordinary English descriptions and comparisons of rates and percentages and for teaching students to read and write such statements correctly.

BACKGROUND

Statistical literacy studies arguments that use statistics as evidence. See Schield 2004a and b. A statistically literate person must be able to read and interpret the data encountered in the news media or in general business. Typically these are macro-statistics: summary data presented in tables and graphs. Schield (2000 and 2001) claimed it can be difficult to read tables and graphs of rates and percentages and to identify the corresponding descriptions and comparisons.

To test this thesis an international survey was conducted by the W. M. Keck Statistical Literacy Project in 2002. This survey is available at www.StatLit.org/Survey. The detailed results of this survey are presented by Schield (2006).

EXPLANATORY FACTORS FOR SCORES

Scores for a group were obtained from the percentage correct for each subject in that group. Classifying subjects by occupation (Q3), the highest overall scores are for college faculty (71%) while the lowest were for K-12 math teachers (45%). Since this data is obtained from a convenience survey, we don’t know if these results are generally true. But if they were generally true, we would say that substantial changes are needed in teacher training for K-12 math teachers.

Classifying subjects by English proficiency (Q6), the highest overall scores are for native English speakers (57%) while the lowest are for those who are still learning English (48%). While this is a smaller effect, the implication is that those who learned English after childhood may need slightly more training.

For this paper, both K-12 teachers and those who learned English after childhood were omitted. Based on their answers to their occupation, three groups were formed: college students (85), professional data analysts (47) and college teachers (37). These college teachers and data analysts are very unusual: 81% of college teachers (91% of data analysts) work in fields that are moderately, highly or extremely quantitative, 78% of college teachers (87% of data analysts) had at least one statistics course and 29% of college teachers (34% of data analysts) had at least two statistics courses.

ANALYSIS OF RESULTS

The terms “part” and “whole” refer to the numerator and denominator of a part-whole ratio. See Figure 1. To repeat, the detailed results of this survey are presented by Schield (2006).

Figure 1: Pie Chart

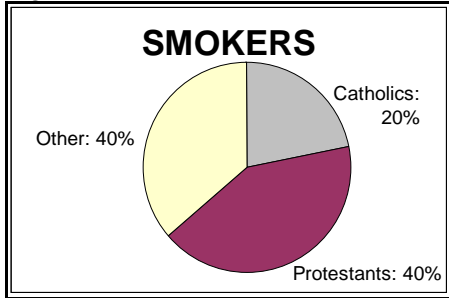
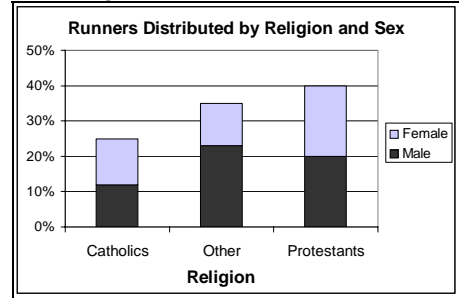


Figure 2: Bar Chart



Reference Figure 1 for these comments (where Smokers is the whole and Catholics are part):

- #1. Students need help in describing a simple percentage in ordinary English. Almost 20% of the students failed to agree with the correct statement that “20% of smokers are Catholic” (Q9).
- #2. Students and data analysts need help in comparing two ratios using ordinary English. Over 60% of both groups mistakenly agreed with this incorrect statement: “Protestants (40%) are twice as likely to be smokers as are Catholics (20%).” (Q10) A correct statement would be, “Protestants (40%) are twice as likely AMONG smokers as are Catholics (20%).”

Reference Figure 2 for these comments (Runners is the whole distributed by religion and sex):

- #3. Students and data analysts need help in comparing two ratios using ordinary English. Over half of both groups agreed with this incorrect statement: “20% of Protestant males are runners.” (Q11) A correct statement would be, “20% of all runners are Protestant males.”

Figure 3: Height vs. Weight

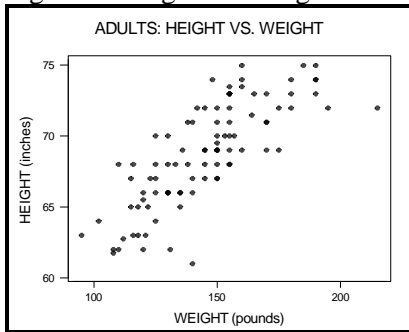
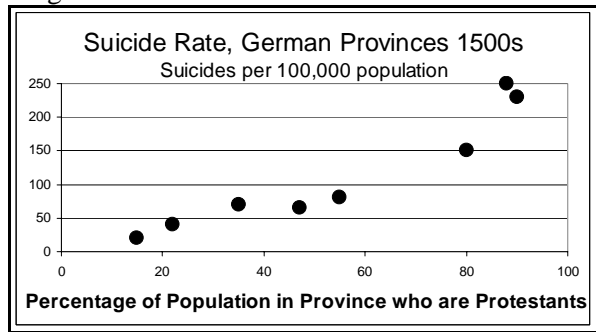


Figure 4: Suicide Rate vs. Protestant Prevalence



- #4. Reference the Figure 3 scatter-plot. For these exploratory items, the first item (Yes/No) is the modal answer for the entire group followed by the percentage of college teachers who agreed with this answer and the statement in question. The percentages of agreement are sorted in descending order within Yes answers and in ascending order within No answers.

- Yes 89% “Adults who weigh more tend to be taller than those who weigh less.” Q12

- Yes 73% The more an adult weighs, the taller they tend to be. Q13
- Yes 73% An adult who weighs more will tend to be taller. Q17
- Yes 54% (Typically) as weight increases, height increases. Q14
- Yes 41% As an adult weighs more the taller they will tend to be. Q18
- No 49% As adults' weights increase, their heights tend to increase. Q15
- No 76% As an adult's weight increases, their height tends to increase. Q16
- No 76% If weight increases, height will tend to increase. Q20

- No 84% “If an adult increases their weight, they can expect to increase their height.” Q19

While one might argue that some of these statements are ill-formed, all of them are used in describing such associations. The most important point is the lack of agreement among college teachers on whether a statement is an accurate interpretation or not. Agreement for all but the two extreme claims never exceeded 80%. The lack of strong agreement indicates the need for rules

and training in this area. The lack of strong support for Q14 is most telling since this statement is very common in describing such associations. Statistical educators must take the initiative in deciding what good practice is.

- #5. Over 25% of the students and the data analysts surveyed did not recognize a proper association between two distinct groups: “*Adults who weigh more tend to be taller than those who weigh less*” (Q12). Around 20% of both groups failed to recognize an improper comparison: “*If an adult increases their weight, they can expect to increase their height*” (Q19). This statement describes a causal change within an individual.
- #6. Reference the Figure 4 scatter-plot for these comments. (On the vertical axis, suicide is the part; on the horizontal axis Protestant is the part.) Almost half the students, data analysts and college teachers surveyed mistakenly presumed that an association between groups could be taken as an association between individuals: this cross-level inference involves the ecological fallacy. Given that “*provinces with a higher percentage of Protestants had a higher suicide rate*”, they mistakenly concluded that “*Protestants are more likely to commit suicide than non-Protestants (are)*” (Q22). This statement views Protestant as a whole whereas the graph showed Protestant as a part. In fact, these non-Protestants were more likely to commit suicide than the Protestants. Perhaps the Catholic minority felt like they no longer belonged.

Table 1: 100% Row Table

RACE	SEX		TOTAL
	Male	Female	
Black	75%	25%	100%
White	50%	50%	100%
Other	40%	60%	100%
TOTAL	50%	50%	100%

Table 2: Two-way half table

	PERCENTAGE WHO ARE RUNNERS		
	Non-smoker	Smoker	Total
Female	50%	20%	40%
Male	25%	10%	20%
Total	37%	15%	30%

Reference Table 1 for these comments. (Each race is a whole and each sex is a part.)

- #7. Around 40% of the students and over a quarter of the data analysts surveyed mistakenly agreed that “*25% of females are blacks*” (Q23) and that “*25% is the percentage of blacks among females.*” (Q25) Correct statements are, “*25% of blacks are female*” and “*25% is the percentage of females among blacks.*” These high error rates may indicate a need for statistical educators to focus on the grammar to form ordinary English descriptions of ratios.
- #8. Around 40% of the students and data analysts surveyed mistakenly thought this table said that “*Females are two times as likely to be white as to be black*” (Q28) when the table supported the claim that “*Females are two times as likely among whites as among blacks.*” These high error rates may indicate the need for statistical educators to focus more on forming ordinary English comparisons of ratios that are presented in simple 100% tables.
- #9. Almost all of those surveyed needs help in forming comparisons using “times more”. About half of all three groups mistakenly agreed that the table supported the claim that “*Whites are two times more likely to be female than are blacks*” (Q29). Supported claims would be either “one time more likely than” or “two times as likely as.” The high error rates on all the statements involving this simple 100% table of percentages may indicate a need for a greater focus on statistical literacy in statistical education.
- #10. Reference Table 2 for these comments. [The margins are averages so the rows (sexes) and columns (smokers and non-smokers) are both wholes while the runners are parts.] All three groups surveyed need help in reading percentage tables that do not add to 100% totals. Around 50% of all three groups mistakenly concluded the table supported the claim that “*20% of runners are female smokers*” (Q30) while over half of all three groups failed to recognize the truth of this claim, “*20% of female smokers are runners.*” (Q32) or that “*Among female smokers, 20% is the percentage of runners.*” (Q34)
- #11. The students and data analysts surveyed need help in seeing the positive value of random assignment in inferring causal connections from statistical connections. Over a third of these

students and data analysts failed to make this distinction. (Q42). Maybe the value of random assignment is getting lost in the technical detail of introductory statistics.

- #12. All those surveyed (students, data analysts and college teachers) need help in recognizing the possibility of Simpson's Paradox: a reversal in an association after taking into account a third factor. Almost half of the respondents in each group did not think it was possible that a research hospital could have a higher death rate than a rural hospital, yet it could have a lower death rate than the rural for patients in good condition and for patients in poor (not-good) condition. (Q43). This reversal is possible if the research hospital had a much higher percentage of patients in poor condition (which caused the higher overall death rate) than did the rural hospital. This reversal is all too common in observational studies.

Table 3: Percentage of Smoking Prevalence

Year	All	Male	Female	White	Black
1955	--	56.9	28.4	--	--
1965	42.4	51.9	33.9	42.1	45.8
1980	33.2	37.6	29.3	32.9	36.9
1990	25.5	28.4	22.8	25.6	26.2

In Table 3, the margin values in the left column are averages – not sums. Thus the columns must be wholes. Since the rows are exclusive, the part must be in the title – smoking.

Reference Table 3 for these comments:

- #13. Most of the students and data analysts surveyed need help in reading tables that don't have 100% totals using "percentage" grammar. Over half the data analyst and almost three-quarters of the students mistakenly thought that "*In 1990, 26.2% was the percentage of smokers who were black.*" (Q44) A correct statement would be, "*In 1990, 26.2% was the percentage of blacks who were smokers.*" Around 60% of the students (40% of the data analysts) mistakenly disagreed with this correct statement: "*In 1990, 26.2% of blacks were smokers.*" (Q 45). These high error rates on such a common table are simply unacceptable.

Age	HIV	Pregnancy	Pap
15-19	14.6	16.1	33.5
20-24	20.0	27.4	68.7
25-29	25.6	25.3	70.9
30-34	18.5	17.4	69.5
35-39	14.2	8.1	62.9
40-44	10.0	4.3	62.7
ALL	17.3	16.0	61.9

Table 5: *Do you think the following statements accurately describe the circled 10.0%?*

Analysis: Since the margin values for ALL are averages, the rows (Ages) are wholes. Medical services (tests) are not exclusive, so they can be either parts or wholes. A part is needed. The title indicates "medical services" may be part. There are no other candidates, so it is a part.

Reference Table 5 for these comments: This percentage table has no 100% totals.

- #14. Almost 80% of the students, over half the data analysts and about a fifth of the college teachers surveyed mistakenly thought that "*10% of the women who received an HIV test were 40-44.*" (Q53) About two-thirds of the students and the data analysts and about a third of the college teachers failed to identify this correct statement: "*10% of these women 40 to 44 received an HIV test.*" (Q54) Around 60% of the students and the data analysts (30% of college teachers) mistakenly thought that "*In Among those women who received an HIV test, the percentage of those 40-44 was 10%.*" (Q 55). A correct statement would be, "*these women 40-44, the percentage who received an HIV test was 10%.*" Having most of these students and data analysts missing these statements is simply unacceptable. Having at least a 30% error rate among the college teachers surveyed may be the underlying cause. Anyone who cannot get read these tables correctly may be classified as statistically illiterate.
- #15. About half of the data analysts and college teachers failed to recognize the truth of this comparison, "*HIV tests were twice as likely to be administered to women 20-24 as to women 40-44.*" (Q58) We realize that decoding "to be administered to women" is not easy. The "to be administered" refers to the HIV test as part but the "to women" does not make women part. Most students (82%), data analysts (60%) and college teachers (81%) mistakenly concluded this was a correct comparison, "*Women 20-24 were two times more likely to have an HIV test than women 40-44.*" (Q59) A correct answer would be either "two times as likely as" or "one time more likely than." Everyone may need help in reading tables that lack 100% totals.

Table 6: Death Rate by leading cause

No. 143. Death Rates, by Leading Cause--States (Top 5 and Bottom 5). Source: 1998 US Statistical Abstract [Deaths per 100,000 resident population estimated as of July 1.]											
STATE	Total	Heart disease	Cancer	Cerebro-vascular dis- eases	Accidents and adverse effects	Motor vehicle acci- dents	Chronic obstructive pulmonary diseases	Dia- betes mellitus	HIV	Suicide	Homicide
1995											
United States	880.0	280.7	204.9	60.1	35.5	16.5	39.2	22.6	(NA)	11.9	8.7
D.C.	1,244.2	302.4	267.2	66.8	34.8	12.3	24.2	39.5	117.8	7.0	56.8
West Virginia	1,107.0	378.9	259.4	67.9	40.4	21.2	60.0	32.8	0.0	15.1	5.5
Florida	1,081.3	351.6	263.5	69.9	38.1	19.8	52.9	26.0	30.8	15.3	8.8
Arkansas	1,075.1	339.8	244.7	91.5	48.8	26.3	45.0	22.4	6.8	14.5	11.6
Pennsylvania	1,059.2	359.7	250.7	68.6	35.3	13.1	43.9	28.2	11.5	12.1	6.5
Missouri	1,021.9	345.3	230.7	72.9	43.5	20.6	46.1	23.4	8.8	13.5	8.9
California	709.8	216.3	162.8	51.4	29.3	14.1	34.2	16.2	20.4	11.7	11.6
Colorado	667.6	172.1	145.9	42.7	39.8	18.6	42.3	14.3	10.9	17.5	5.7
Hawaii	643.1	196.0	156.4	51.5	27.6	12.0	20.4	14.2	10.4	12.0	4.9
Utah	560.6	148.1	108.6	39.9	32.4	17.2	24.1	21.3	4.8	14.8	3.9
Alaska	423.0	90.6	95.1	24.0	56.2	16.1	17.7	9.3	5.0	17.1	8.9

Reference Table 6 for these comments. Death rates for the US rates in the top row are averages so the individual state rows delimit wholes. The rates in the Total column are sums so the columns are parts. "Death" modifies "rate" so "death" is a part along with the column heading.

Everyone needs help in reading a table of rates where one index delimits the whole while the other delimits the specific part. About a fifth of the students did not accept this true statement: "In 1995, the death rate due to motor vehicle accidents was 16.1 per 100,000 Alaskans." (Q60). Over half the students and data analysts mistakenly accepted this false statement: "In 1995, for those in motor vehicle accidents, the death rate was 16.1 per 100,000 Alaskans." (Q61). Over 60% of the students (over 30% of the data analysts and college teachers) mistakenly accepted this false statement: "In 1995, the rate of motor vehicle accidents was 16.1 per 100,000 Alaskans." (Q62. The statement omits the word "death"). Over two-thirds of the students and data analysts mistakenly accepted this false statement: "In 1995 for Alaskans who were in motor vehicle accidents, the death rate was 16.1 per 100,000." (Q63). These high error rates indicate the part-whole problem exists with rates as well as percentages.

Respondents were asked to evaluate the survey on an ordinal scale: "strongly agree," "moderately agree," "moderately disagree" and "strongly disagree." Among all respondents,

- 91% agreed that "College students should be able to read these tables and graphs" (Q69),
- 90% agreed that "These tables and graphs are the kind I need to be able to read" (Q68),
- 75% agreed that "This survey was much more difficult than I thought it would be" (Q64),
- 64% agreed that "This survey was much more subtle than I thought it would be" (Q65),
- 62% agreed that "I felt considerable discomfort in taking part or all of this survey" (Q67)
- 50% agreed that "This survey was unnecessarily tricky" (Q66).

SUMMARY:

The average error rate was about 50% for college students, 45% for data analysts and 30% for college teachers. Using the data analysts' 80th percentile score as the goal, then only about 5% of students, 20% of data analysts and 45% of college teachers reached that goal.

RESEARCH IN USING AN ON-LINE PROGRAM

Burnham and Schield (2005) developed a web-based program to help students practice writing ordinary English statements that accurately describe and compare rates and percentages presented in different kinds of tables and to give students immediate feedback on their mistakes. See www.StatLit.org/RSVP. Before this program was available, the class time needed for students to develop these skills in writing descriptions and comparisons of rates and percentages was at least 6 to 12 hours – based on having taught over a thousand students over a period of 10 years. This class time has been reduced by at least 50% using this on-line program. Using this program has helped make it possible to offer statistical literacy entirely on-line at Capella University. See Isaacson (2005). Capella student comments include "a cool tool", "an invaluable tool", "a great help," "a great resource and very practical," and "extremely helpful."

CONCLUSION

In reading a pie chart (Q9), 19% of students misread a description. In comparing two slices within a pie chart (Q10), the error rate was 62% for students (65% for data analysts). In a 100% row table, 44% of students (28% of data analysts) misread a description while 46% of college teachers misread a “times more” comparison (Q29). In comparing two percentages (Q59), the error rate for college teachers (81%) was about the same as for students (82%) but higher than for data analysts (60%). The possibility of Simpson’s paradox (Q43) was not recognized by 68% of data analysts and 41% of college teachers. In reading a table of rates (Q61), the error rates were 60% for students and 53% for data analysts.

Statistical educators should review – if not recommend – the language used to describe an association in a scatter-plot. “Typically, as X increases, Y increases” (Q14) was accepted by only 47% of professionals and only 54% of college teachers. The lack of agreement among college teachers on various ways of describing an association indicates the need for rules and training.

Of these respondents, 91% agreed that “*College students should be able to read these tables and graphs*” (Q69). Yet 75% agreed that “*This survey was much more difficult than I thought it would be.*” This response clearly indicates that reading graphs and tables of rates and percentages is much more difficult than calculating a simple percentage in elementary school.

If we use the 80th percentile score of the data analysts as the goal, then only about 5% of students, 20% of data analysts and 45% of college teachers reached that goal. This shortfall is a wakeup call for help and for action. Statistical educators may be seen as educationally negligent if almost all of their students cannot interpret the data presented in tables and graphs.

Decoding graphs and tables of rates and percentages and then describing and comparing the data is not easy. But now statistical educators have both the rules and the tools to teach students how to read, interpret and communicate summary data. Statistical educators should accept the responsibility for establishing the rules for students to decode tables and graphs of rates and percentages and to write ordinary English descriptions and comparisons of these rates and percentages. Statistical educators should then accept responsibility for teaching students how to do this correctly if students and future data analysts and teachers are to be statistically literate.

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