Young Adults Making Sense of Data

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Young adults were presented with raw data involving a number of variables and asked to produce a report that highlighted any "interesting aspects" that they observed. The approaches taken varied from simple frequency information through to scatter plots and the use of ratios to consider the relationships between three variables. Although the use of sophisticated statistical techniques was not expected, the limited use of even basic techniques was surprising, given the increased emphasis on Chance and Data in school curricula.

In 1987 Frances Curcio argued the need for students to be given opportunities to describe the relationships and patterns that they observe in data (Curcio, 1987, p.391). Since then, Chance and Data together have been incorporated more fully into the mathematics curriculum, identified as a separate important strand of the curriculum in many Australian states. Although this may mean that more students are learning important statistical techniques, such as graphing and calculating measures of central tendency, it is not entirely clear to what extent Curcio's broader program has been implemented. In particular, students who can perform statistical processes when specifically requested may *not* be able to choose for themselves when such skills ought to be implemented. The work of Gal, Rothschild, and Wagner (1990) and Watson and Moritz (1999), for example, suggests that of those students who understand how to calculate the mean, many may not appreciate its significance or usefulness when dealing with data sets. Their research showed that when comparing two samples of different size very few students chose to determine means despite knowing the mechanics of the process. Li and Shen (1992) highlight that students presenting graphical data may do so inappropriately.

One tool that has been used to examine students' statistical decision-making abilities is the data cards protocol, first described in 1995 (Watson & Callingham, 1995; Watson, Collis, Callingham, & Moritz, 1995), and briefly outlined below. This protocol lets students choose which aspects of the data to analyse and decide on the best representation. Initially intended for primary and secondary students, in the current study it has been adapted for use with young adults in order to ascertain which data handling skills are brought to bear by those who have completed compulsory schooling. This work continues the author's earlier study of the statistical cognition of young adults, that examined the conclusions drawn from data by young adults, and also considered their understanding of the relationship between a sample and its corresponding population (Chick, 1999). The purpose of the current research is to examine what aspects of data young adults choose to consider, and what statistical techniques they apply in their analysis.

Method

There were 32 students (21 males and 11 females) involved in this study. In 1997 all were enrolled in a terminating first year university mathematics service course, intended for students from the science, arts, commerce, and medicine faculties undertaking subjects requiring basic calculus. This course had no statistics component. The students had completed Year 11 or Year 12 mathematics subjects that included the study of basic statistical ideas,.

including collecting, organising, displaying and interpreting numerical data together with calculating summary statistics. Most were also exposed to straightforward techniques associated with normally distributed data.

The *data cards protocol* has as its central focus a set of data about 16 individual children. For each child the data comprise information about name, weight, eye colour, favourite activity, number of fast food meals consumed per week, and age. In most implementations of the protocol the data are presented to subjects on 16 individual cards (hence the name of the protocol), but for the current study they were presented in a table, with the child's gender specifically identified as well. The data for the protocol, as developed by Watson et al. (1995), are included in the Appendix. Subjects were provided with this table and asked to identify and justify any interesting features of the data. For the current study, the protocol was implemented as an assignment question:

> Examine the data and produce a report which highlights any aspects of the data which you think are interesting. You are free to choose your approach to this problem and what to include in your report. If you make any claims about the data be sure to back them up with suitable evidence.

The students prepared written reports in response to this question; these responses provided the data for this research. It must be emphasised that the task was purposefully open-ended, so that students were free to choose both the particular aspects that appealed to them and the actual methods of analysis. Some students capitalised on this opportunity by considering a wide variety of relationships, while others were either unsure what actually constituted a satisfactory response, or did what they felt would be just enough to satisfy the assignment marker. Caution must therefore be applied to our consideration of quantitative aspects of the analysis.

For the purposes of this paper a number of aspects of the students' responses were considered. Every comment pertaining to one or more of the data card variables was noted, together with the number of variables involved. In addition, the nature of any statistical analysis associated with the comment was noted. For example, some students referred to graphs they had drawn, some calculated averages, while others just gave a written description presumably based on what they had observed in the original table of data. It must be noted that because the data set was so small, many students almost certainly observed its features from the actual data without utilising any formal statistical methods. They may well have regarded such observations as obvious and not needing any formal evidence; this factor must be borne in mind when considering the students' limited use of graphical and statistical techniques.

Results and Discussion

Variables Considered by Students when Analysing the Data

Analysing the responses from the 32 students identified 219 instances where the students made an observation concerning one or more of the variables from the data. In many cases, however, these observations referred to the variables of only a few of the children in the data set, rather than an appropriately selected sample. As an example, one student made a claim about weight and gender, but as supporting evidence referred to two specific individuals from the data set. This was still classified as a two variable observation; in addition its inappropriateness was noted. The number of variables considered by students and the number of instances of such observations are given in Table 1. No student restricted their analysis to examining just one variable at a time, in contrast to results achieved with primary school children (see Watson et al., 1995), although 18 students (39 instances) made at least one single variable observation. Many of these observations involved the gender variable, highlighting the fact that there were equal numbers of boys and girls in the data (10 students), or noting the age range or average age (11 students).

Table 1
Number of Variables Considered by Students (N = 32)

Number of variables considered	Number of students	Number of instances
1 variable	18	39
2 variables	32	123
3 variables	25	43
4 or more variables	11	14

All 32 students made at least one observation regarding two variables. One student *only* considered two variable relationships (three instances), with an additional student considering both one and two variable information but no more. All but seven students referred to three variable combinations, with five students considering three or more such combinations. Of the 11 students considering four or more variables, many did so by recognising the existence of other influencing variables in a two variable association. As an example, eight students (11 instances) acknowledged the interdependence of at least four of the five variables, age, fast food, favourite activity, gender, and weight. It should be noted, however, that not all of them did this by considering the actual data, relying instead on external knowledge.

For two variables, the most common pairs considered were fast food/favourite activity (considered by 19 students); favourite activity/gender (17 students); fast food/gender (16 students); age/fast food, fast food/weight (10 students each); and age/gender, eye colour/gender, and favourite activity/weight (9 students each). Not surprisingly, the only pairs that were not considered by any students were eye colour paired with weight or age, and pairs involving name. For three variables by far the most common triple was fast food/favourite activity/gender (11 students), with other combinations considered by five or fewer students. Name was never one of the three variables, and eye colour was considered only once, although it was one of the four variables considered by two additional students.

Statistical Techniques Utilised by Students

Many basic statistical techniques were implemented by students in support of their claims. These techniques included various graphical approaches; calculating means, modes, percentages and fractions; producing tables; and determining age/weight ratios for investigating the relationship between three variables. In contrast, for some claims many students did not present any formal statistical arguments. Instead, they wrote the claim and appeared to assume that it was clearly visible from the raw data. The following quote from one student serves as an example: "It is seen that males watch more TV than females do as a favourite activity, while females tend towards activities such as netball and swimming." At the very least an ordered table or some appropriate numerical values could have accompanied this claim. This student's whole report was in a similar vein.

Table 2 lists the techniques utilised by the students, linked to the number of variables considered. Sometimes a single table or graph was used to support a number of observations, so the values in Table 2 do not give the total number of tables or graphs produced. Most of the techniques listed are self-explanatory. Lists of data or tables without labelled columns were classified as *Quasi tables*; the use of ranking words, like "more" or "least," together with other worded claims was classified as *Worded description*; and *Other numerical techniques* includes the use of ratio. All but eight instances of *Sum or total* were simple frequencies (e.g., number of males and females), with the eight non-trivial examples involving total number of fast foods for certain categories of individuals. These often included an average calculation as well. Nobody used the median, presumably because the students did not think it was particularly appropriate for the data.

Table 2
Statistical Techniques Used by Students (N = 32) and Number of Variables Considered

	Single variable		Two variables		Three variables		More than three variables		Total occur-rences	
Statistical technique used	S	I	S	I	S	I	S	I	S	I
Table	0	0	11	32	6	11	1	1	11	44
Quasi table	2	2	4	4	2	2	1	1	8	9
Graph	1	1	9	12	3	3	2	4	10	20
Worded description	10	20	28	72	18	28	11	13	32	133
Fraction	1	1	4	4	0	0	0	0	5	5
Percentage	2	2	7	11	2	2	1	1	8	16
Average (mean)	3	3	18	42	5	7	5	5	21	57
Mode	1	1	9	9	2	2	1	1	11	13
Sum or total	12	13	15	25	4	6	1	1	21	45
Other numerical technique	12	12	9	13	9	10	2	2	18	37

Note. S = number of students utilising the technique; I = number of instances of the technique.

Most of the 36 tables produced by the students, and referred to on 44 occasions, were sub-tables or rearrangements of the original table of data. One student based all her claims on sorted versions of the original table, sorted according to the criterion of interest. A few students produced 2 × 2 contingency tables, but these merely gave frequency information such as for the number of students in the four categories determined by gender and the activity or passivity of favourite activity. No student produced a more complex 2 × 2 contingency table involving three variables similar to that shown in Table 3. Claims involving three (or more) variables were dealt with using other techniques.

Table 3
Fast Food Consumption as a Function of Gender and Favourite Activity

Mean number of fast food meals consumed per week		Favourite Activity: Active (N=6)	Favourite Activity: Passive (N=10)
Gender	Male (N=8)	2.0	7.8
	Female (N=8)	0.7	2.6

Note: "Active" includes football, netball, and swimming; "Passive" includes boardgames, TV, and reading.

Given the emphasis on graphical techniques in early statistical study and the effectiveness of graphs as a means of illustrating characteristics of data, it was surprising to find that only ten students used this form of analysis, producing a total of 17 graphs (which were referred to on 20 occasions). Previous research with Grade 5/6 students (Chick & Watson, 1998) found that many students did not attempt a graphical representation until *after* prompting by the researchers. Graphs may not be seen as an automatic "tool of choice" for dealing with data; this may be exacerbated by the fact that producing a graph requires more effort than alternative statistical approaches. The availability of spreadsheet and graphic calculator technology may reduce this tendency, although this occurred only to a limited extent in the current study. Five students appeared to take advantage of computer spreadsheet programs to produce their graphs, but not always with success. Figure 1 provides a classic example of what can occur when students use a program's features without thinking about whether such features are appropriate. Li and Shen (1992) have previously reported students' similar difficulties with graphical representations.

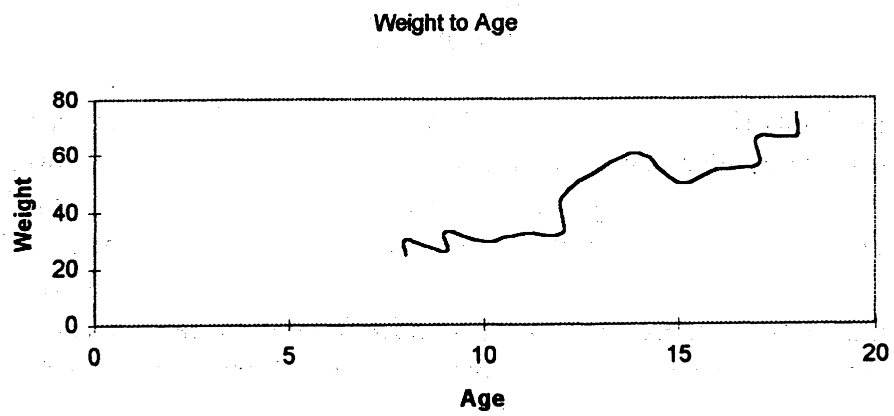

Figure 1. Weight to Age graph produced by a student using a spreadsheet program.

Hand drawn graphs were not totally free of problems either. Figure 2 shows a graph of weight against age, presented as a bar graph rather than a scatter plot and with a poorly labelled horizontal axis. Three students drew more appropriate scatter graphs, but only one drew a trend line or possible line of best fit. The student who plotted Figure 3 and its corresponding graph for males alluded to a trend line when he wrote that the two graphs show "that the males have a faster constant weight rate, while the females' weight is slow and inconsistent" [spelling and punctuation corrected]. Nobody calculated any correlation coefficients, but this may not have been part of their previous statistical experience.

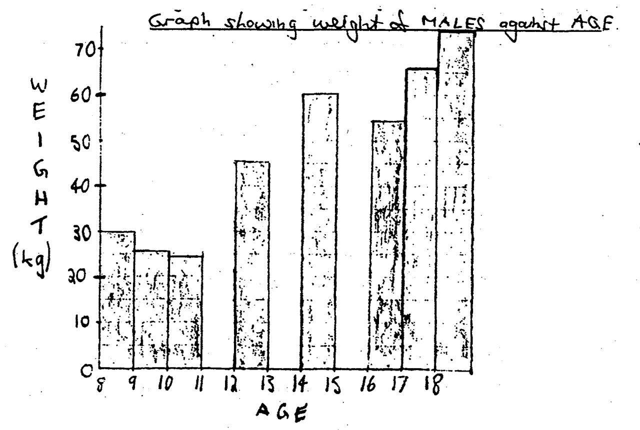

Figure 2. An example of an in appropriate bar graph format.

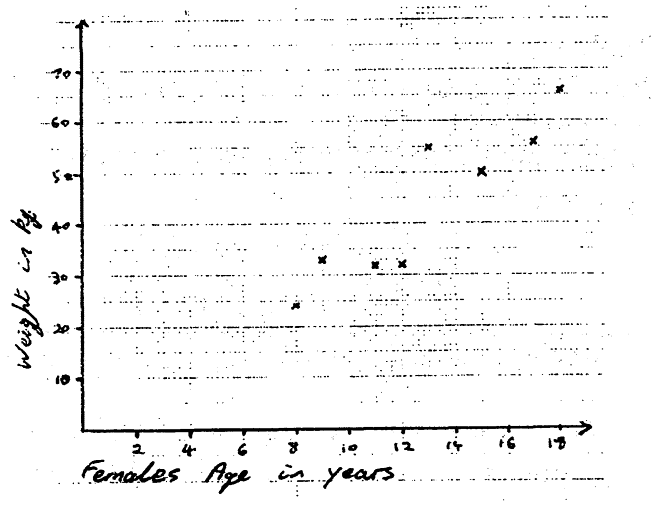

Figure 3. Scatter graph with no trend line.

Three students produced reports with no statistical or graphical information at all. They made claims such as "The females on average eat less fast food than the males" without actually calculating any statistical measures. One referred to individual data to support the points he discussed, as illustrated by: "[four names] are all male gender, have television watching as their favourite activity and consume 10, 7, 8 and 12 fast food meals respectively. They each consume many more fast food meals than any other school children presumably because it is more time consuming to prepare a meal than to purchase one … ." The prevalence of descriptive analyses is further illustrated by the fact that of the 219 claims made, 64 (29%) involved worded descriptions only, with no supporting statistics. A further seven students had no graphs or tables in their reports but at least calculated summary statistics such as proportions or means.

A total of 40 claims (in addition to the 64 worded descriptions) used a single statistical technique; 14 of these involved sums or totals (mostly trivial) and 11 involved means. The majority of the 115 claims involving two or more techniques included worded descriptions. These words did not just recount the values obtained but gave extra clarification and highlighted relationships. The following quote illustrates the use of words to give meaning to the statistical values: "The 'sporty' subjects [=children] consume far less fast food than 'other activities' subjects, 5.2 meals per week compared to 1.3 meals per week." Tables were involved in 41 of the multi-technique claims, and means were used in 46, with 19 claims using both. Students often prepared tables or partial tables and then calculated the means of variables of interest.

Two students dealt with three variables by determining the ratio of weight to age for all the children in the data set and then considered this in relation to a third variable (fast food consumption in one case and favourite activity in another). Both students added the ratios to the table of data, but neither completely capitalised on this quantitative information. One gave a worded description about the claimed relationship and used a statistically appropriate term: "There is for example, a high correlation between a large number of meals and a large age/weight ratio. This would be explained by the fact that fast food is generally unhealthy and fattening." No correlation was actually *demonstrated*, however; it is possible that she thinks it is clear from the tabulated data. The other student took the averages of the weight/age values for the 'active' children and the 'inactive' children, and claimed the 'inactive' group's average is higher. Unfortunately, the actual averages were not given.

Conclusion

Before drawing some tentative conclusions it must be reiterated that the open-ended nature of the task and the lack of guidance to students about the associated expectations certainly influenced what students did. Furthermore, the students may not have been particularly interested in the data set, as they had no say in its generation. One student, whose report was a litany of largely unrelated observations supported by worded descriptions, concluded his report by saying "The list of silly aspects goes on and on." This is, perhaps, not an unreasonable response. It would appear, nevertheless, that most students took the task seriously, and that they approached it in the way intended: as a data analysis task in which the object was to seek trends and summary information.

The students sought and found many relationships in the data, demonstrating them using a variety of techniques. They did not, however, always choose the best technique for the job, nor carry it out in the correct way. The students often used their previous experience to explain some of their observations, when, in fact, the data itself could have been used, particularly with connections among age, weight, fast food, favourite activity, and gender. Finally, despite the explicit request to present suitable evidence for claims, there were many unsubstantiated assertions.

The results of this study and the author's earlier work (Chick, 1999) suggest that despite the increased emphasis on chance and data there is still more to be done to ensure that students have the ability to call on appropriate skills and understanding in statistical contexts. Although it is conceivable that the limited use of graphical and statistical information may be a consequence of the small data set (with properties that can certainly be determined to some extent "by inspection"), many students do not seem to appreciate the need for and value of quantitative evidence. It would appear, then, that Curcio's 1987 call needs to be reiterated and emphasised for older students: they need to be provided with the opportunity to collect data and present it in meaningful and statistically valid ways.

References

Chick, H.L. (1999). Jumping to conclusions: Data interpretation by young adults. In: J.M. Truran & K.M. Truran (Eds.) *Making the difference.* Proceedings of the 22nd annual conference of the Mathematics Education Research Group of Australasia (pp. 151-157). Sydney: MERGA.

Chick, H.L., & Watson, J.M. (1998). Showing and telling: Primary students' outcomes in data representation and interpretation. In: C. Kanes, M. Goos, E. Warren (Eds.) *Teaching mathematics in new times.* Proceedings of the Twenty-first annual conference of the Mathematics Education Research Group of Australasia (pp.153-160). Brisbane: MERGA.

Curcio, F.R. (1987). Comprehension of mathematical relationships expressed in graphs. *Journal for Research in Mathematics Education, 18,* 382–393.

Gal, I., Rothschild, K., & Wagner, D.A. (1990, April). *Statistical concepts and statistical reasoning in school children: Convergence or divergence?* Paper presented at the meeting of the American Educational Research Association, Boston, MA.

Li, K.Y., & Shen, S.M. (1992). Students' weaknesses in statistical projects. *Teaching Statistics, 24*(1), 2-8.

Watson, J.M., & Callingham, R.A. (1997). Data cards: An introduction to higher order processes in data handling. *Teaching Statistics, 19,* 12-16.

Watson, J.M., Collis, K.F., Callingham, R.A., & Moritz, J.B. (1995). A model for assessing higher order thinking in statistics. *Educational Research and Evaluation, 1,* 247-275.

Watson, J.M., & Moritz, J.B. (1999). The beginning of statistical inference: Comparing two data sets. *Educational Studies in Mathematics, 37,* 145-168.

Appendix: Table of Data for the Data Cards Protocol

Table 4
Table of data supplied to students for interpretation

Name	Gender	Age	Favourite Activity	Eye Colour	Weight (kg)	Fast food meals consumed per week
Adam Henderson	M	12	Football	Blue	45	5
Andrew Williams	M	14	TV	Blue	60	10
Anna Smith	F	11	Boardgames	Brown	32	1
Brian Wong	M	9	Football	Green	26	1
David Jones	M	8	TV	Blue	30	7
Dorothy Myers	F	15	Swimming	Blue	50	2
JanelleMacDonald	F	18	Reading	Blue	66	4
Jennifer Rado	F	9	Boardgames	Green	33	4
John Smith	M	10	Football	Green	29	0
Kathy Roberts	F	12	Netball	Brown	32	0
Mary Minski	F	13	Reading	Green	55	3
Peter Cooper	M	16	Boardgames	Green	54	2
Rosemary Black	F	8	Netball	Brown	24	0
Sally Moore	F	17	Reading	Brown	56	1
Scott Williams	M	17	TV	Blue	66	8
Simon Khan	M	18	TV	Brown	74	12

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