Human Use of Metric Measures of Length

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We asked 80 introductory psychology students to estimate the sizes of 30 common objects, and to give their own heights. Subjects were free to use either metric or imperial measures. We found that 43% used metric measures exclusively. No one exclusively used imperial measures. Use of metric measures varied for different objects. The object for which most subjects (99%) used metric measures was a $10 banknote. The "object" for which least subjects (61%) used metric measures was the subject's own height. The percentages using metric measures were reduced for little-known objects, old objects, horizontal and vertical (rather than unspecified) dimensions, and objects with sizes between 2 and 5 m. The use of systems of measurement is an aspect of human behaviour that warrants more empirical attention.

Between 1971 and 1976, New Zealand introduced the metric system of measures (e.g., metres, degrees Celsius, grams), superseding the imperial system (e.g., feet, degrees Fahrenheit, pounds). At that time, there was a large-scale public education campaign to encourage people to use metric measures (Fletcher, 1973). Since that time, metric measures have been taught in New Zealand schools. Nevertheless, imperial measures are still present. People are exposed to them via media from countries that have used imperial measures more recently, such as the U.S.A. (which only recently began to convert to the metric system, Levitan, 1992), and even from New Zealand media (e.g., the television programme CrimeWatch gives heights of suspects in centimetres and in feet and inches). Presumably, also, people familiar with the imperial system in 1976 may persist in using these units.

The introduction of metric measures is an example of a governmental attempt to change people's behaviour through legislation, advertising and education. Surprisingly, it seems there has been no long term assessment of the change. How effective was the campaign to encourage New Zealanders to use metric measures?

As part of another ongoing project into the perception of, and memory for, size, we asked introductory psychology students to estimate the sizes, from memory, of 30 common objects. Subjects were free to use either metric or imperial measures. These data offer us a "covert" measure of willingness to use metric measures of length in a group who were born shortly before metric measures were introduced.

Method

Subjects

Eighty introductory psychology students volunteered for this study in order to meet the requirements of their psychology paper. Of these, 36 were male, and 44 female. Their ages ranged from 18 to 24 years.

Procedure

Subjects were each presented with a three-part questionnaire. Questionnaires were administered during July and August 1992. Part one of the questionnaire contained questions on biographical information, including height, and on experience with viewing distant objects. Part two consisted of 30 pages, one for each object, given in a random order for each subject. Objects were ones that would have been frequently seen by the subjects, but which were not visible during the experiment (a list of the objects is given in Table 1).

For each object, subjects were asked to rate how familiar they were with the object on a 7-point Likert scale, and to estimate the linear size of one or more of its dimensions. Subjects were instructed not to estimate the sizes of objects they had never seen. Part three consisted of questions about strategies used for estimating sizes.

The objects were chosen to represent a wide range of sizes and familiarities. Some of them were more likely to have only been seen from a great distance, whereas others may have been touched by the subjects every day. Sizes ranged from a few centimetres to over 100 metres. In all, 54 estimates were requested of each subject.

Results

In all, 91% of responses given were in metric measures; 43% of subjects used metric measures exclusively, 58% used imperial measures at least once, and no subject used imperial measures exclusively. While metric measures were used at least once by all subjects, the majority used imperial measures at least once, indicating a "pluralism" about use of length measures.

The objects, and the numbers and percentages of subjects using metric measures, are given in Table 1. Percentages for objects which required more than one dimension to be estimated are averaged over the dimensions. To assess differences in frequencies of use of metric measures for different objects, we conducted one-group chi-square tests for each object, using the average use over all objects to generate expected frequencies.[1] The results of these chi-square tests are given in Table 1. The mean exclusive use of metric measures for all the objects was 88%[2].

The instance for which metric measures was used least is the subject's own height. Here only 61% used metric measures. Every object was estimated in imperial measures by at least one subject.

Eighteen subjects used a combination of imperial and metric measures for different dimensions of the same object on at least one occasion; no subject did this for more than four of the objects. Seventeen of the twenty-three objects for which estimation of more than one dimension was required were estimated in this fashion. For three of these objects (flagpole, Polytechnic chimneys, and dashed line on road), four cases were found for each. These were also the only three objects where the ratio between actual dimensions to be estimated equalled or exceeded 10:1, yet there seemed to be no consistency between cases as to whether it was the large or small dimension that was measured in metrics.

Table 1

The objects, dimensions estimated (dims; d = diameter, h height, l = length, w = width), number of subjects responding(n), number using metric measures (n m), percentage using metres (% m), and value of the chi square testbetween obtained use of metric and average use over all objects.

Object	dims	*n*	*n* m	% m	chi square
Subjects height	h	80	49	61	52.16****
Flagpole	h,d	16	10	63	9.47**
Kinetic sculpture	h,w	23	18	78	1.92
Polytechnic chimneys	h,d,w	32	26	81	1.25
Robbie Burn's	h,l	67	55	82	1.99
Iron railings	h,l	35	29	83	.78
War memorial	h	19	16	84	.22
Volkswagen "Beetle"	h,l	77	65	84	.79
Union Street sculpture	h,w	33	28	85	.26
Parking meter	h	80	69	86	.16
Centennial memorial	h,l	23	20	87	.01
Parking signs	h,d	77	68	88	.02
Painted head	h,w	71	63	89	.07
Supermarket trolley	h,l	80	71	89	.08
Gargoyle	l,w	28	25	89	.06
Clock face	d	76	69	91	.51
Unicol chimney	h,w	55	50	91	.66
Dashed lines on road	l,w	80	73	91	.92
Zebra crossing lines	l,w	80	73	91	.92
Neon sign	h,l	74	68	92	1.19
Electrical insulator	h,d	64	59	92	1.18
"Bridge" sculpture	h,l	65	60	92	1.26
Cobble stones	l,w	78	72	92	1.51
Road markings	l,w	79	73	92	1.6
Television Transmitter	h,w	45	42	93	1.31
Speed limit roadsign	d	79	74	94	2.58
Lens of traffic light	d	80	75	94	2.69
Cover of text book	l,w	80	75	94	2.69
Clearway road signs	d	72	68	94	3.01
Albany Street width	w	74	72	97	6.29*
$10 note	l,w	80	79	99	9.02**

Note * p < .05
** p < .01
**** p < .0001

Predicting Metric Usage

We explored our data with a variety of statistical techniques in an attempt to predict metric usage.

By subject age, sex, and use of metrics for own height. No significant differences were discovered in the use of metric measures for different ages of subjects, although it must be stressed that a very narrow range of ages was represented in this experiment (18-24 years). Similarly, no significant difference was found between metric use by male and female subjects $F(1,78) = 1.74$, $p > .19$. Subjects were no more likely to estimate the sizes of the thirty objects in metric measures if they had given their height in metric measures, $F(1,78) < 1$.

By subjects' strategies. Subjects used as many as six different strategies including comparing the object with other objects of known size (59% of subjects) and imagining the object as seen from its usual viewing location (58% of subjects). However, percentage of metric use was essentially the same from subjects who used and did not use particular strategies (all ps > .05 for t-tests).

By familiarity with objects.[3] There was a positive correlation between the number of subjects who responded for each object and the percentage of these who used metric measures, $r = 0.63$, $p \leq .0001$. That is, the greater the number of subjects who knew an object, the more likely any of those subjects would use metric measures. We also found a positive correlation between average familiarity and use of metric measures, $r = 0.65$, $p \leq .0001$.

It seems from these two correlations either that better-known objects were, for some unknown reason, intrinsically more likely to be measured in metres, or (as is more likely) that the subjects who knew the lesser-known objects were the ones most likely to use imperial measures. This could indicate one of two things: (a) that the more observant subjects were using imperial measures, or (b) that subjects who better knew the local surroundings were using imperial measures. Subjects brought up locally may be more likely to use imperial measures.

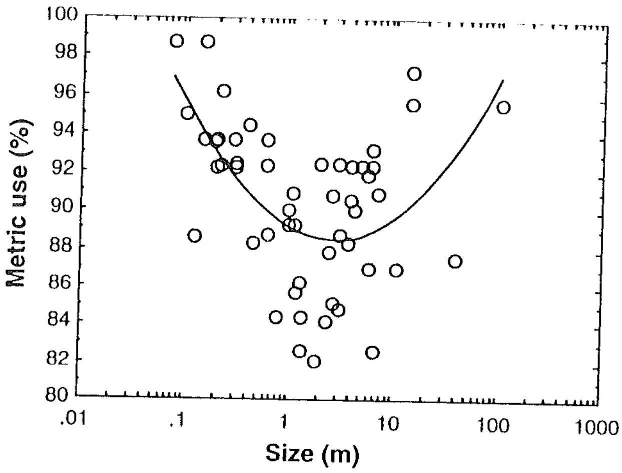
By accuracy. We computed an unsigned measure of accuracy proportional to the variance of the differences between the true size and the estimated size divided by the difference between true size and mean estimated size. This yielded a measure of accuracy such that high values indicated high accuracy and low values indicated low accuracy. We then correlated this with percentage using metric measures for each object. It did not successfully predict metric usage.[4]

By size of objects. When the proportion of subjects using metric measures was regressed on the logarithm of object size, there was a significant quadratic regression, $r = .57$, $p < .0001$, indicating that use of metric measures reaches a minimum for objects between 2 and 5 m in size. The scattergram and regression function are shown in Figure 1. A similar regression ($r = .60$, $p < .0001$) was found when the logarithm of estimated, rather than actual, size was used.

By dimensional aspect. Dimensions were divided into roughly equal groups according to whether they were normally seen as vertical, horizontal or unspecified (n of 17, 20 and 15, respectively). Unspecified dimensions were those where the object was commonly seen from a variety of angles or was round in shape. When the three categories were compared by ANOVA for the use of metric vs imperial measures, a strong effect was revealed, $F(1,50) = 13.18$, $p < .0001$. Both vertical (88%) and horizontal (90%) dimensions were less frequently measured in metric terms than the unspecified dimensions (94%).

Figure 1

Quadratic regression of percentage use of metric measures against the logarithm of object size. The regression equation is $y = 88.587 - 3.245(\log x) + 3.488(\log x^2)$. Each point represents one dimension of an object.



By object age. Finally, objects were classified into three roughly equal groups according to whether they were old, intermediate or new (n of 19, 18 and 15, respectively). Old objects included stone statues and building parts that have existed in the city for many years, whereas new items included such items as road signs, text book and the bank note. These yielded means for use of imperial measures of 12%, 8% and 9% respectively. When the three categories were compared by ANOVA for the use of metric versus imperial measures, the effect was significant $F(1,50) = 4.94$, $p < .02$. Post hoc tests showed that old objects were far more frequently measured in imperial terms than intermediate or new objects.

By multiple regression. Given what we have learnt about relationships between metric usage and the above variables individually, we can attempt to combine the predictors in a stepwise multiple regression. This will tell us if any of the individual predictors are accounting for the same variance of metric use.

A stepwise regression was performed, using object age, dimensional aspect, average familiarity, number of subjects knowing the objects, and logarithm of object size as predictor variables. Aspect was recoded into two levels: specified (horizontal/vertical) and unspecified. For logarithm of object size, if there was more than one dimension, the average was taken, and the logarithm of this was used. The criterion variable, proportion using metric measures, yielded 29 cases.[5] The stepwise regression had a limiting F value of 4. That is, a variable had to produce an F value of more than 4 to be added to the regression.

When the regression was performed, aspect and number of subjects remained as the only two significant variables F (2,26) of 4.01 and 4.52 respectively. The remaining variables each returned an F < 1. Table 2 shows the simple and partial r values for these two variables. The absence of the other variables from the multiple regression solution suggests that their predictive value is accounted for by variation in aspect and number of subjects.

Table 2

The simple and partial r values of significant variables from the stepwise regression

Variable	simple *r*	partial *r*
Aspect	.57	.36
Number of subjects knowing object	.58	.38

General Discussion

It appears that the Government's attempts to phase out the use of imperial measures were only partially successful. While the majority of subjects use metric measures for the majority of objects, many of our subjects use imperial measures of length some of the time.

Some subjects even use a combination of imperial and metric measures for different dimensions of the same objects. Subjects tend to prefer imperial measures for object dimensions normally considered horizontal or vertical and for familiar objects.

Why do subjects persist in using imperial measures of length? We can think of at least three possible reasons, none of which, by itself, is entirely satisfactory.

First, when making estimates, people may compare the object to be estimated with some reference object of known size. We note that imperial measures were, originally at least, designed to correspond to known reference objects. The foot was a human foot's length, the inch a thumb's width, and the furlong was "a furrow's length" (Boulding, 1980). Metric measures, with their basis in physical absolutes and standards, could not hope to be as readily used by the average person. There is evidence for the use of reference objects when people are asked to estimate sizes (e.g., Joynson, Newson, & May, 1965), and we have shown that a majority of subjects reported using such a strategy. Inspection of Figure 1 may allow us to identify at least one such reference object that people use. Imperial measures were used most for human height (note that this point is not plotted on the figure) and for objects of about that size, suggesting that body size is a reference object. Outside of this range, metric measures appear to hold sway. The reference-object explanation may also account for the preference for using imperial measures for vertical and horizontal dimensions of objects, in that it is easier to visualize humans standing or lying. The explanation, however, begs the question of why a person's height is more likely viewed in imperial measures. Furthermore, it does not explain the lack of significant correlation between the use of metric measures for size estimates and for subject's own height.

Second, there may be some heuristic value in being able to swap between two measurement systems that have different numerical properties. For example, the work of Huttenlocher, Hedges, and Bradburn (1990) suggests that people will tend to go from one unit of measurement (e.g., inches) to a coarser-grained unit (i.e., feet), as the size of objects to be estimated increases in order to maintain use of one-digit numbers (see also Banks & Hill, 1974). Imperial measures afford subjects several extra length categories (e.g., inches, feet, yards) over those of the metric system (e.g., cm, m, km). We can search for such transitions in Figure 1. The points on each arm of the regression line at which subjects go from using imperial measures proportionately more of the time to using metric measures consistently occur at about 0.3 m (1 foot) and about 30 m (100 feet). Subjects seem to prefer to use feet except when that would require them to use fractions or unwieldy three-digit numbers. This numerical-properties explanation would lead us to expect that centimetres would have been preferred up to about 10, above which inches would have been preferred. Close examination of our data, however, revealed no such trend.

Third, government decree and the educational system are not the only sources of information about measurement systems. It is possible, of course, that the parents of our subjects may have persisted using nonmetric measures at home, the source of much learning. If so, what our subjects learnt at school tells only part of the story. Significantly, correlations between the number of subjects recognising objects and the use of imperial measures could indicate regional differences in the use of metrics. Subjects most familiar with

Dunedin (and therefore presumably having lived here the longest) use imperial measures more often. Dunedin is often viewed as one of New Zealand's more conservative and traditional cities. If true, there may have been some resistance to attempts to change to metrics.

Alternatively, these subjects may still be living at home, and therefore may be still within their imperial-measures-using parents' "sphere of influence". From this home-environment explanation, however, one might predict that imperial measures would be more prevalent for objects local to Dunedin, and that metric measures would be more prevalent for generic objects found throughout the country.[6] Our data revealed no such difference.

While the three explanations we have proffered all have deficiencies, they may be partial explanations for the complex use of metric and imperial measures that we have documented. Other factors may refine the prediction of choice of measurement scale. In any case, New Zealand's dual measurement scales provide a useful opportunity for testing current issues of people's conceptual categories (cf. Huttenlocher, Hedges, & Duncan, 1991; Poulton, 1979).

References

Banks, W. P., & Hill, D. K. (1974). The apparent magnitude of number scaled by random production. *Journal of Experimental Psychology, 102*, 353-376.

Boulding, K. (1980). Numbers and measurement on a human scale. In D. F. Bartlett (Ed.) The Metric Debate. Boulder; *Colorado Associated University Press.*

Fletcher, G. (1973). *The New Zealand metric officer's handbook.* Auckland: Metric Aids.

Huttenlocher, J., Hedges, L., & Bradburn, N. (1990). Reports of elapsed time: Bounding and rounding processes in estimation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 196-213.

Huttenlocher, J., Hedges, L. V., & Duncan, S. (1991). Categories and particulars: Prototype effects in estimating spatial location. *Psychological Review, 98*, 352-376.

Joynson, R. B., Newson, L. J., & May, D. S. (1965). The limits of over-constancy. *Quarterly Journal of Experimental Psychology, 17*, 209-216.

Levitan, D. (1992). The metric system is just around the corner. *Government Finance Review, 8*(2), 11-12.

Poulton, E. C. (1979). Models for biases in judging sensory magnitude. *Psychological Bulletin, 86*, 777-803.

Author's Notes

1. Another techique we might have was the Cochran Q Test. However, this test requires that any subjects with missing data be excluded. We did not want to do this for two reasons. First, we would have excluded most of our subjects. Second, as we shall see later, the subjects who remained would not have been typical in their use of metric measures.
2. "Exclusive use" of metric measures indicates that where more than one dimension was estimated of an object, all dimensions were given in metres.
3. Subjects own height was not considered one of the esimated dimensions for these regressions, as it was assumed that it was known rather than estimated. An outlier (height of the municipal chambers flagpole) was also removed from these calculations. Only 20% of the subjects estimated a height for this object, and of these, six (38%) used imperial measurements.
4. Accurancy could, however, be predicted from metric usage. Object sizes became less accurate as the proportion of subjects using metric measures tended towards 90% ($r = .475$, $p < .005$), resulting in a U-shaped regression line.
5. See footnote 3.
6. We are grateful to an anonymous referee for making this suggestion.

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