Comparison of the values for A, the asymptotic maximum calculated for the arm counts, with the gross absorption measured from stool excretion of tracer, demonstrated excellent correlation.

Although this technique of arm counting does not yield values for absolute absorption of calcium, it does permit comparisons of relative absorption in the same subject before and during administration of substances affecting absorption, as well as comparisons between individuals with disturbances of mineral metabolism. Results are obtained within a few hours and no blood sampling or urine or stool collections are necessary. The amount of isotope required for accurate results is small, which permits studies to be carried out in children as well as in adults and allows repetitive studies in the same individual under different conditions of diet and drug therapy. The technical procedures are simple and rapid, and suggest that the technique may be of value in large-scale population studies of calcium absorption and survey protocols. Of greatest interest is that the in vivo procedure yields data describing the kinetics of the initial phase of transfer of calcium from the gastrointestinal tract to the bone and the modification of this phase by disease, diet, and pharmacologic agents.

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Scaling of Apparent Viscosity

Abstract. *Observers made numerical judgments of the apparent viscosities of silicone liquids whose absolute viscosities ranged from 10.3 to 95,000 centipoises. Judgments were made by three procedures: shaking or turning a bottle containing the liquid, stirring the liquid with a rod with the eyes blindfolded, and stirring with the eyes open. For all these methods of judging, apparent viscosity was found to grow as the absolute viscosity raised to a fractional power. The exponents ranged from 0.42 to 0.46. The perception of viscosity follows the psychophysical power law that seems to govern prothetic perceptual continua.*

Judgments of relative viscosity, which can be made by tactual-kinesthetic or by purely visual means, have practical application in parts of the food industry (*1*), but they are also of interest in their own right. The purpose of the experiments reported herein was to determine how quantitative judgments of apparent viscosity depend on physical viscosity, as ordinarily defined, and to see whether this perceptual continuum follows the psychophysical power law that governs the growth of apparent magnitude on prothetic continua (*2*).

Procedure. The stimuli were seven blends of clear silicone fluid having viscosities 10.3, 95, 920, 12,500, 29,000, 61,000, and 95,000 centipoises (*3*). Approximately 150 ml of each fluid was placed in a clear, screw-cap, glass jar whose capacity was about 300 ml. These cylindrical glass jars were 7 cm in diameter and 9 cm high.

In each of three experiments a group of ten observers made two judgments of each stimulus. The stimuli were presented twice in a different irregular order to each observer. Written instructions were given. Those for the first experiment read as follows.

"I will give you a series of containers filled with liquids that vary in viscosity (internal friction). Shake each container and judge how viscous the liquid seems to be by assigning a number to it. Call the apparent viscosity of the first liquid any number that seems to you appropriate. Assign to the succeeding liquids numbers proportional to their viscosity. For example, if a liquid seems five times as viscous, assign a number five times as large as the first. If it appears to you 1/10 as viscous, assign a number 1/10 as large, and so on."

In the second experiment we employed a different group of 10 observers. This time the observers were blindfolded and instructed to stir the liquid with a round plastic rod (22 by 0.6 cm), making three turns to the right and three to the left.

The third experiment was the same as the second, except that the observers watched the liquid while they stirred it. Ten observers were used, six of whom had served in one or the other of the two previous experiments.

In all experiments the first stimulus presented was selected irregularly, except that neither of the two extreme stimuli was ever presented first.

Results. The twenty magnitude estimations of each stimulus in each experiment were used to compute a median and a geometric mean. The agreement generally obtained between these two measures suggests that magnitude estimations give distributions whose skewness can be corrected by taking logarithms. The geometric means of the data, of which both coordinates are logarithmic, are plotted in Fig. 1.

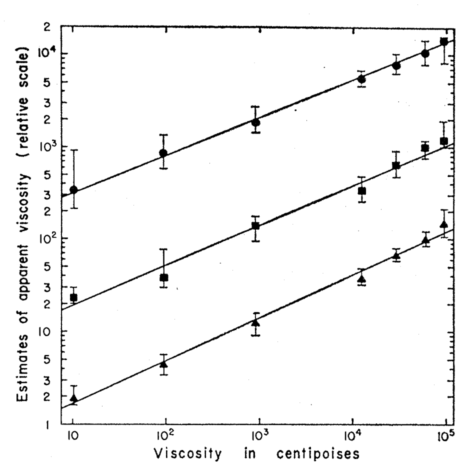

Fig. 1. Each point represents the geometric mean of 20 numerical judgments of apparent viscosity, two judgments by each of ten observers. Each power function represents a separate experiment. Circles: The observer watched the liquid while shaking or turning its container. Squares: The observers stirred the liquid while blindfolded. Triangles: The observers watched the liquid while stirring it. For clarity, the functions are separated vertically by one log unit. The exponents (slopes) are 0.42, 0.43, and 0.46. The vertical bars represent the interquartile ranges of the 20 judgments of each stimulus.

The tendency of the geometric means to fall close to a straight line in a log-log plot shows that apparent or subjective viscosity is a power function of physical viscosity. The exponents for the three experiments, given by the slopes of the visually fitted lines in Fig. 1, are 0.42, 0.43, and 0.46. Since the procedure of magnitude estimation often gives a slight underestimation of the value of the exponent, a representative round-number value for apparent viscosity may be 0.5.

There appears to be little if any difference attributable to the sense modality used in the evaluation of a given ratio of viscosities. In the first experiment the observers shook or turned the glass jars and watched the fluid. Since shaking had no effect on the more viscous liquids, the jars had to be turned slowly and the judgment of viscosity was based almost wholly on visual effects. In the second experiment the observers could see nothing, but they could feel the viscosity with the aid of the rod. In the third experiment they both saw and felt the viscosity. These procedural differences seemed to have no consequential effect on the power functions.

Variability. Since each observer was allowed to choose his own modulus or "unit" for his subjective scale, this factor was partialed out before the variabilities were computed. For each experiment a grand mean of the logarithms of all the judgments was first obtained. The mean of the logarithms of the estimations by each observer was then subtracted from the grand mean and the difference was added to the logarithm of each of that observer's estimates. This operation leaves unchanged the slope of the magnitude function for each observer, but it minimizes the sum of the squared deviations of his estimations around the regression line for the group (*4*).

The vertical lines in Fig. 1 show the interquartile range of the judgments after the variability attributable to the modulus has been removed. The extent of the variability suggests that apparent viscosity is not a particularly difficult judgment to make.

Inverse Judgments. The fact that apparent viscosity grows approximately as the 0.5 power of physical viscosity was confirmed in two additional experiments. The procedures were the same as for the first and third experiments on viscosity, except that the observers were asked to judge fluidity instead of viscosity. The geometric means of the magnitude estimations of the inverse aspect approximated a reciprocal function, an outcome that has been demonstrated with nine other continua (*5*). And as typically happens, the fluidity function departed from a good power function in the direction of being concave downward.

The observers reported more difficulty in judging fluidity than in judging viscosity, but this may have been due to their prior experience with judgments of viscosity. Before more is said about judgments of fluidity, it would be desirable to obtain a new population of observers and to counterbalance the order of judgments. A more uniform (logarithmic) spacing of the stimuli may also prove desirable (*6*).

Relation to other continua. Apparent viscosity belongs to the group of perceptual dimensions that seem to depend on more than a single sense modality. Another example of this class is the apparent hardness produced when rubber samples are squeezed between thumb and finger, which involves touch, pressure, and muscular strain. The method of magnitude estimation has shown that apparent hardness grows as the 0.8 power of physical hardness (*7*). Another presumably complex continuum is the roughness of emery cloths stroked with the fingers. The apparent roughness grows as the 1.5 power of the diameter of the grit particles (*8*). No obvious explanation suggests itself for the wide differences among the exponents that govern these various continua, but the invariance of the principle that, on every prothetic continuum, equal stimulus ratios produce equal subjective ratios remains a matter of deep interest.

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30 March 1964

Origin of Noctilucent Clouds

In a recent report of observations of a noctilucent cloud in Arizona, Meinel and Meinel (*Science*, 3 Jan. 1964, p. 38) demonstrate that its drift vector indicated an origin from the Pacific Missile Range area. They write: "No data confirming the launching of a ballistic missile are on hand; however, the evidence seems quite conclusive."

But the evidence seemed inconclusive to me, and I queried the director of information at Vandenberg Air Force Base. He wrote, "A Minuteman ICBM was launched from Vandenberg AFB, California on 2 November 1963 . . . at approximately 2:30 P.M." This datum certainly adds weight to the missile-exhaust hypothesis of the origin of these clouds, but not enough, in my opinion, to exclude other hypotheses. The evidence for the hypothesis now rests only on the following data: nine of the clouds were observed on days when space vehicles were launched; and of these nine, two were traced to the Pacific Missile Range area.

Several questions are not answered by the hypothesis. If the clouds are formed by missile exhaust, how can this happen in the manner of natural noctilucent cloud formation, as suggested by Meinel, Middlehurst, and Whitaker (*ibid.*, 20 Sept. 1963, p. 1176)? No explanation is offered for the extraordinary shape and size of the Flagstaff cloud reported by McDonald (*ibid.*, 19 Apr. 1963, p. 292), or for the fact that it was accompanied by a smaller cloud of the same shape. How could missile exhaust be converted into two rings, the larger of which was 35 km wide? And why are there missile launchings that are not followed by sightings of these clouds?

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