to hydrated $Na^+$ or $K^+$ as the case may be. In crystals, at least, the sizes of the ions can be compared easily. In $KAl(SO_4)_2.12H_2O$ the $K^+$ ion is surrounded by six water molecules at a distance from $K^+$ to oxygen of 2·94 Å (ref. 2) (all distances will be centre-to-centre distances). The distance to the centre of the entire water molecule is perhaps 3 Å. Adding to this 1·45 Å, which is half the distance between water molecules in pure water, the maximum radius of the $K^+$ ion with one hydration shell is about 4·45 Å. This is similar to the maximum radius of $TEA^+$ in crystalline tetraethylammonium iodide[3], which is 4·6 Å if the radius of the terminal —$CH_3$ group is taken as the van der Waals radius of 2 Å (ref. 4). $TEA^+$ (and also $Tn\text{-}PA^+$) probably does not have a hydration shell in solution[5], so nothing more need be added to the 4·6 Å. The fact that the larger $Tn\text{-}PA^+$ ion (5·9 Å by the same calculation, with arms fully extended[6]) interferes with the $Na^+$ current suggests that in solution $Na^+$ may be more hydrated than $K^+$. In $NaAl(SO_4)_2.12H_2O$ the $Na^+$ ion is surrounded by six water molecules at a distance of about 2·5 Å (ref. 2). In solution, the first hydration shell may be more complete, since it is sterically possible to fit in more than six water molecules. A second layer added to a closely packed first layer (that is, with water molecules 2·9 Å apart) would be at a distance of about 4·2 Å from the $Na^+$, making the maximum radius about 5·65 Å. These radii must not be taken too seriously, but they do suggest that in solution the hydrated $K^+$ ion is similar in size to $TEA^+$, and the hydrated $Na^+$ similar to $Tn\text{-}PA^+$. $Tn\text{-}PA^+$ perhaps competes with $K^+$ when its hydrocarbon arms are not fully extended. The reason why $TEA^+$ and $Tn\text{-}PA^+$ stop up the channels is less apparent. These ions are less radially symmetrical than $Na^+$ and $K^+$, and this may allow them to approach more closely and thus bind more tightly to a (hypothetical) negatively charged group in the membrane. The fact that both $TEA^+$ and $Tn\text{-}PA^+$ are effective only when inside the axon indicates a difference between the inside and the outside of the membrane.

Fortified with this evidence that the $K^+$ ion in solution has one hydration shell while the $Na^+$ ion has two (a view that is widespread but not conclusive), it is easy to proceed to a simple theory of the cation selectivity of the membrane. In Fig. 3 the large circle represents a site selective for $Na^+$. The site has a negative charge, but its precise character is unimportant so long as it is a good fit for a hydrated $Na^+$ ion and its circumference is rigidly fixed. Entry of a hydrated $K^+$ ion (medium size circle) would only partially fill the site, leaving an appreciable space. Water molecules, the smallest available molecules, could not fit, and the space would remain empty, even though its total volume was equal to that of a number of water molecules. Creation of such a space would require a great deal of energy, for to make a hole the size of a single water molecule in an aqueous solution requires as much energy as the transport of a water molecule from the aqueous to the vapour phase. Still more energy would be

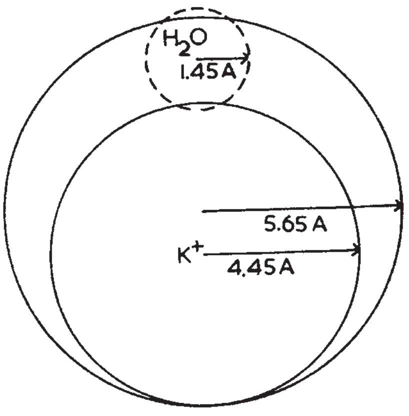


Fig. 3

required to lower the dielectric constant of the space[7]. The large energy barrier resulting from these two factors would prevent the entry of the $K^+$ ion. The hydrated $Na^+$, on the other hand, would be too large to enter a $K^+$ selective site, which would be similar to the $Na^+$ site but smaller. This selectivity hypothesis does not depend on the exact value of the radii used here, which are not likely to be absolutely correct.

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# PSYCHOLOGY

## A Two-hour Reading Course

It seems likely that the improvements brought about by reading efficiency courses are largely due to such factors as increased concentration rather than the training of eye movements or 'perceptual skills'[1,2]. It has been suggested[3,4] that increasing one's concentration while reading, or 'reading more actively' (a term frequently used by instructors), results in an increasing use of the redundancy of the passage being read, making the immediate stimulus more easy to recognize and process further.

To test the practical implications of such a hypothesis a single session reading course was designed to include the following features:

(1) An initial 450-word passage followed by a comprehension test consisting of ten simple open-ended questions.

(2) Short lectures on bad reading habits: (*a*) inadequate concentration; (*b*) vocalization or sub-vocalization; (*c*) unnecessary regressions.

(3) Reading a short selection of statistical approximations to English (first, third and sixth orders) to illustrate the existence of constraint in the language without reference to meaning.

(4) An illustration of the effects of context on word recognition. This was accomplished by flashing several words on a screen, initially in isolation then with a context sentence which predicted it to a small degree, finally with a context sentence which predicted the word to a high degree. The exposure time and contrast were chosen so that about a third of the students saw the word on the first exposure, a further third on the second exposure and nearly all when the word was briefly exposed with a strong context.

(5) Illustrations of the notion of backwards redundancy on the level of both words and ideas, indicating to what extent regressions may be unnecessary.

(6) Five 3-min sessions of silent reading of a 'Pelican' or similar non-fiction volume, during which students were expected to keep in mind what they had just been told.

(7) A final passage for reading with a comprehension test.

The whole procedure lasted just less than 2 h, and there were interspersed frequent statements of the type "You *can* all improve your reading efficiency" and similar exhortations and encouragements.

Table 1

| | Sub-group 1 ($n=36$) Initial test— A | Final test— B | Sub-group 2 ($n=26$) Initial test— B | Final test— A |
|---|---|---|---|---|
| Mean efficiency | 211 | 243 | 161 | 242 |
| Mean efficiency | 211 | 252 | 158 | 252 |
| Mean improvement | 33 per cent | | 80 per cent | |
| Median improvement | 19 per cent | | 45 per cent | |
| Wilcoxon T | 140 ($P < 0.002$) | | 11 ($P < 0.0001$) | |

*Note:* The word 'efficiency' is defined as the product of speed of reading in words per minute and the fractional comprehension.

The students were personnel on a U.S. Air Force base; three lectures have been given, with a total of sixty-two students. Two passages, $A$ and $B$, were used, some of the students reading $A$ initially and $B$ finally and the rest vice versa. The time for reading was taken by the students to the nearest 5 sec and the reading efficiency was calculated as the product of the speed of reading in words per min and the fractional comprehension score. The results are shown in Table 1.

It is clear that the group as a whole improved its reading efficiency in the 2 h. The best estimate of the average improvement is about 30 per cent, one student improving by 500 per cent and fifteen students performing less well on the final test than on the initial test. The mean group improvement found on commercial courses, which take from 15 to 27 h, is about 50 per cent.

Three points must be made about the present course. First, the course was held in the evening following a full day's work for the students, and the course itself was reportedly exhausting. Accordingly, the final scores might be artificially low. Secondly, as opposed to this, the only real test of a course of this kind is the long-term effect. It is likely that many of the students in the absence of further encouragement will not maintain their improved performance. Thirdly, the course makes no direct attempt to extend the students' capacity, merely to show them what kinds of relevant knowledge they already have. For some of the people, for example, an extensive vocabulary training would be necessary. This was pointed out to the classes, as were a few fairly obvious "reading techniques" such as the advantages of reading the summary of a book before tackling the main body, and the different strategies which one might use when reading material for specific purposes; but for some people more detail of this kind would be necessary. It was clear, however, that many of the students had never realized that language was redundant, nor that they need not read every word of a text. In some cases a short course of this kind could be as effective as a longer one.

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## When Recognition is No Better than Recall

RECENT findings have thrown doubt on the validity of the generalization that it is easier to recognize than to recall. Davis *et al.*[1], using a list of fifteen two-digit numbers as stimuli, found that if all ninety possible numbers are presented in a recognition test, performance is no better than recall when both are tested immediately after the presentation.

I have made a similar comparison of recognition and recall using a list of English counties as stimuli. (This research was carried out before the recent boundary changes.) Counties preserve the advantage numbers have of being a clearly defined, limited, and enumerable category, but whereas all subjects can generate all ninety two-digit numbers at will, they are not able to list all the counties.

Table 1. MEAN RECALL AND RECOGNITION SCORES FOR COUNTIES

| Stimuli | Recall | Recognition |
|---|---|---|
| Commonly named | 5·45 | 5·27 |
| Rarely named | 3·86 | 5·27 |
| Average | 4·65 | 5·27 |

The experiment was carried out in two stages. In the first, response availability was examined. Eighty-six young newly-enlisted men, tested in groups of 10–20, were asked to write down the names of all the English counties. Ten minutes were allowed, by which time all had stopped writing. A mean number of 19·99 out of a possible 40 were listed (*S.D.*, 5·45). The frequency with which any particular name was listed ranged from 93 per cent of subjects (Hampshire) to 9 per cent (Huntingdonshire).

In the second stage, two lists of counties were selected as stimuli for memory experiments in which free-recall and recognition measures were compared. One list consisted of the six most frequently named counties. The other consisted of the six least frequently named ones. To lengthen the lists of stimuli sufficiently to exceed the memory span and thus induce some errors, six additional counties from the middle of the response-availability range were added, three at the beginning and three at the end. The same six buffer items were used with both lists and they were not counted when assessing performance.

The stimuli were printed on large cards and were presented one at a time with a 5-sec exposure and a 1-sec interval between items. Memory was tested immediately after presentation. Alternate members of each group were required to recognize the stimuli from a list of all forty counties typed in random order, while the remainder had a blank sheet of paper on which they had to write out the twelve they had seen in any order. Three minutes were allowed for this test. Three groups of fresh subjects were tested with each list, the order of presentation of the critical stimuli being varied each time. Altogether, twenty-two subjects were tested under each condition.

The mean performance on the critical stimuli is shown in Table 1. It can be seen that although recognition is markedly better than recall for the rarely named counties and is better overall, with the commonly named counties recall is slightly superior.

Similar tests have been carried out with a 40-min delay between presentation and test, during which time the subjects were kept busy with other, unrelated, experimental tasks. With the commonly named counties the mean performance on recognition was 5·07 (fifteen subjects), while that on recall was 4·31 (sixteen subjects). The superiority of recognition under this condition was statistically significant ($P < 0·02$). With two-digit numbers, however, introduction of the delay did not lead to significant advantage for recognition. The relevant scores were: recognition, 8·07 (forty subjects); recall, 7·85 (forty subjects) $P > 0·25$.

The picture is thus rather complex, but it would appear that on immediate test recognition is no better than recall for readily available responses. A fuller account of these experiments and their implications will appear elsewhere.

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## Vertical Sinusoidal Vibration as a Psychological Stress

MOST modern vehicles move, by design or accident, to some extent in all six theoretical axes (movement along and rotation around the three orthogonal axes, fore-aft, side-side, and up-down). Whole-body vibration is likely to be applied to human occupants most frequently and with greatest power in the vertical (seat to head) direction,