tance, optimum performance was obtained when cues were presented entirely in the auditory modality. The advantage of vocalizing may therefore be hypothesized to rest partly on the fact that more cues were in general available to *S*, but more particularly on the fact that *S* was presenting himself with a cue in a preferred modality, that is, auditory. Introspective evidence obtained from the *S*'s supported this, and also suggested that *A* gave (insignificantly) superior recall to *RA*, *RA*$^+$ and *V* because *A* provided less 'distraction' during the task of perceiving and storing the presented list. The fact that *S*'s were already highly practised at *R* and *V* lends greater force to the present finding that pure auditory presentation gave recall at least as good as voicing-at-presentation. Why auditory immediate memory should in fact be so efficient —at least under the conditions described here—remains to be answered. It should be noted that the significant interaction of subjects with vocalization suggests that there might be an important element of individual variability as regards preference for one presentation-method or another.

This work was done while I held a studentship at Trinity College, Cambridge. I thank A. J. Watson and Prof. O. L. Zangwill of the Cambridge Psychology Laboratory for their advice and encouragement, and Dr. A. G. Worthington of the Psychology Department, Queen's University, for statistical advice.

D. J. Murray

Department of Psychology,
Queen's University,
Kingston, Ontario.

[1] Murray, D. J., *Quart. J. Exp. Psychol.*, **17**, 47 (1965).
[2] Mowbray, G. H., and Gebhard, J. W., in *Selected Papers on Human Factors in the Design and Use of Control Systems*, edit. by Sinaiko, H. W. (Dover Publications Inc., 1961).
[3] Day, W. F., and Beach, B. R., *Air Material Command, U.S.A.F. Tech. Rep.* No. 5921 (1950).
[4] Buschke, H., *Nature*, **195**, 101 (1962).
[5] Henmon, V. A. C., *Psychol. Rev.*, **19**, 79 (1912)
[6] Woodworth, R. A., and Schlosberg, H., *Experimental Psychology* (Methuen, 1955).
[7] Edwards, A. L., *Experimental Design in Psychological Research* (Holt, Rinehart and Winston, 1960).

Effects of a Drug and Immediate Memory

A new test of immediate memory was recently suggested by Buschke[1]. $N - 1$ items drawn from an ensemble of N are presented, and the task is to name the missing item. An experiment is described in which this technique, the 'missing scan method', was used to evaluate the effects of sub-anaesthetic doses of nitrous oxide on immediate memory. The results seem to cast light on underlying processes. It is suggested that two forms of storage may be distinguished—that used depending on the presentation-rate of items—and that one form is especially susceptible to drug effects.

Random auditory sequences, each consisting of seven letters drawn from the ensemble *A*–*H*, were presented at two rates: two items per sec (fast), and one item every 2 sec (slow), to subjects fully equilibrated under low doses of nitrous oxide. Practice sequences were given during induction of the gas. Sixteen student and technician volunteers (aged 18–33), used as their own controls, received 15, 25 or 35 per cent nitrous oxide and air (control) on successive days according to a 4 × 4 factorial design. Dose-effect curves for errors and latencies of correct responses (geometric means) are shown in Figs. 1*a* and *b* respectively.

There was no evidence of impairment of performance accuracy in the 'fast' condition up to and including the 25 per cent dose, but in the 'slow' condition as little as 15 and 25 per cent nitrous oxide increased errors significantly (2-tailed Wilcoxon tests, $P < 0{\cdot}01$; $P < 0{\cdot}05$ resp.). Thus, since disruption of stimulus registration by the drug should result in a greater drug effect at faster rates, there was no evidence of a drug impairment of this stage. A drug effect on retention is therefore suggested. There were no significant differences between the input conditions under any dose of nitrous oxide. But under air there were fewer errors at the slower rate (2-tailed Wilcoxon, $P < 0{\cdot}01$). The results are therefore not consistent with a simple trace decay theory, since under air control subjects did better when they had to wait longer before responding. The drug appears to have disrupted some process in the 'slow' condition. The results suggest some sort of interference with memory traces and resemble Fraser's[2] findings on the effects of ageing.

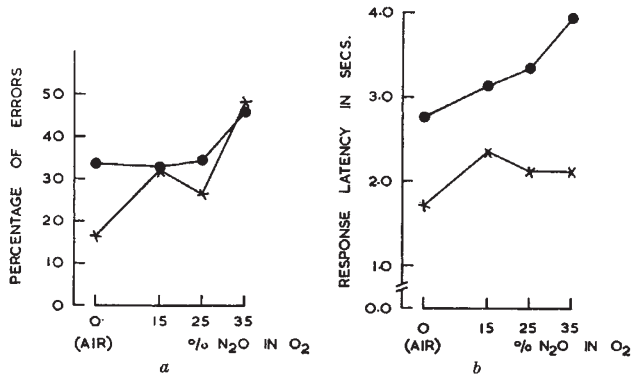

Fig. 1. *a*, Dose-effect curves for errors; *b*, dose-effect curves for response latencies. Rates of presentation: ●, fast; ×, slow

As Figs. 1*a* and *b* suggest, accuracy of performance in the 'slow' condition was prone to drug impairment, response latency was not. In contrast, accuracy in the 'fast' condition was resistant to impairment (except at the highest dose), but latency increased progressively with dose (Jonckheere trend test; $P = 0{\cdot}012$). The longer response latencies for the 'fast' rate should be noted: the difference between the conditions was very highly significant (analysis of variance on mean log latencies; $P < 0{\cdot}001$).

Introspective reports seem relevant in accounting for the latency difference between the 'fast' and 'slow' rates of presentation, and in explaining why the two input conditions were differently affected by nitrous oxide on the two performance measures. Subjects reported that in the 'slow' condition they formed a spatial image of the ensemble and had time to cancel each item as it arrived, so that at the end of presentation they had only to 'read out' the missing item. Many reported that the drug tended to interfere with this image. In the 'fast' condition, subjects reported that the items arrived too fast to cancel as they occurred, and were first stored as sound, being transferred to the spatial image at the end of presentation.

Assuming the introspective evidence of two separate stores is valid, the latency data imply that the time for transfer of the items from the first to the second store was normally about a second, and that it was progressively increased by nitrous oxide. The error data suggest that the second store may normally be the more efficient, but is especially vulnerable to drug effects.

Further work is in progress to evaluate this two-store hypothesis of immediate memory. Drugs promise to be a useful tool for this purpose.

This work was supported by grant *MH*-03313 from the U.S. Public Health Service, and was carried out under the supervision of Prof. Arthur Summerfield and Dr. Hannah Steinberg.

C. Berry

Departments of Psychology and Pharmacology,
University College, London.

[1] Buschke, H., *Nature*, **200**, 1129 (1963).
[2] Fraser, D. C., *Nature*, **182**, 1163 (1958).