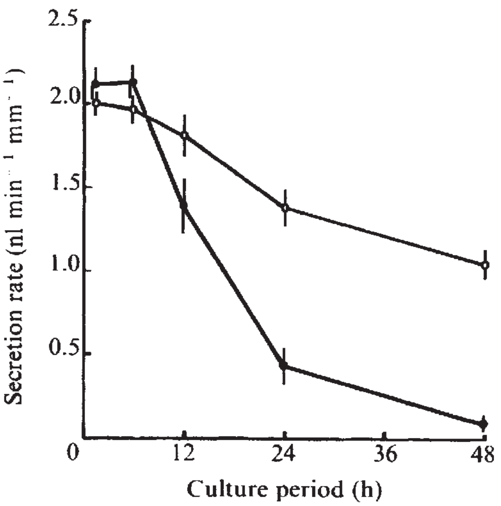

Fig. 3 Ecdysterone switches off Malpighian tubule fluid secretion *in vitro*. Tubules from a P-72 stage larva were cultured in a 50 : 50 mixture of artificial haemolymph–Graces culture medium containing 1 μg ml^{-1} ecdysterone (●) or 1 μl ml^{-1} ethanol (○). After various periods of time the tubules were transferred to artificial haemolymph and the rate of secretion was measured. Each point is the average of 15–20 tubules ±1 s.e.m.

with their isolation and degradation in autophagic vacuoles, and a reduction in apical and basal channels are early events in the remodelling process. Both of these events are induced by ecdysterone *in vitro* (ref. 8 and unpublished data).

Fluid transport continues in Malpighian tubules at larval–larval moults (my unpublished data), even though a pulse of ecdysterone occurs in the blood to trigger moulting. This suggest that the inhibitory effect of ecdysterone is

Table 1 Loss of fluid secretion at pupation in different insects

Insect	Secretion rate in last larval stage	s.e.m.	n	Secretion rate in early pupal stage	s.e.m.	n
Calpodes ethlius	31.0 nl min^{-1}	1.2	20	0 nl min^{-1}	0	18
Danaus plexippus	5.7 nl min^{-1}	0.6	12	0 nl min^{-1}	0	12
Tenebrio molitor	0.25 nl min^{-1} mm^{-1}	0.03	15	0 nl min^{-1} mm^{-1}	0	15

modulated by some other factor such as juvenile hormone, since topical application of juvenile hormone to last larval stage *Calpodes* prevented the tubules being switched off at the larval–pupal moult.

Ecdysterone stimulates fluid secretion in tsetse fly tubules within minutes, suggesting a short-term physiological regulation[1]. In contrast, the functional and structural changes described in this report are longer-term developmental processes which require hours or days. Also, unlike tsetse fly tubules, no short-term stimulation or inhibition of fluid secretion was observed within the first few minutes or hours following applications of 1 μg ml^{-1} ecdysterone to larval or adult *Calpodes* Malpighian tubules.

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1. Gee, J. D., Whitehead, D. L. & Koolman, J. *Nature* **269**, 238–239 (1977).
2. Bollenbacher, W. E., Vedeckis, W. V., Gilbert, L. I. & O'Connor, J. D. *Devl Biol.* **44**, 46–53 (1975).
3. Lageux, M., Perron, J. & Hoffmann, J. A. *J. Insect Physiol.* **22**, 57–62 (1976).
4. Delbecque, J. *et al. C. r. hebd. Séanc. Acad. Sci., Paris* **281**, 309–312 (1975).
5. Maddrell, S. H. P. *Adv. Insect Physiol.* **8**, 199–331 (1971).
6. Diamond, J. W. & Bossert, W. H. *J. gen. Physiol.* **50**, 2061–2083 (1967).
7. Berridge, M. J. & Oschman, J. L. *Tissue Cell* **1**, 247–272 (1969).
8. Ryerse, J. S. *Proc. Microscop. Soc. Can.* **4**, 48–49 (1977).
9. Ramsay, J. A. *J. exp. Biol.* **31**, 104–113 (1954).

Difficulties in auditory organisation as a possible cause of reading backwardness

LEARNING to read and write involves auditory perception, for the child must learn how different kinds of sounds are written. It might seem, however, that although auditory perception is essential to reading, it would not be a significant source of difficulty, for, apart from a few exceptional cases, most children who have difficulties with reading can hear perfectly well, and can discriminate and understand the words which they signally fail to read[1]. But discriminating words is not the only aspect of audition involved in reading. The child must also be able to group together words which are different but which have sounds in common. If he is to learn the rules of reading and writing he must understand that 'hat', 'cat' and 'mat', though different, nevertheless have a sound in common. We report here results which suggest that difficulties in this kind of grouping may be a significant source of difficulty in learning to read.

We compared a large group of children of normal intelligence, but 18 months or more behind the average reading skill for their age, with a group of younger children also of normal intelligence, whose reading skills were normal for their age and were the same as those of the backward readers. Details of the two groups are given in Table 1. Although the two groups were approximately equal in reading ability and were both of normal intelligence for their age, the backward readers were on average over three years older than the other group.

This is a novel kind of comparison and our reason for making it was to distinguish between cause and effect. The vast majority of studies of reading backwardness and all the studies of auditory perception in backward readers[2-4] compare backward with normal readers of the same age and intellectual level, the only difference between the groups being in how far they have learned to read. The trouble with this traditional design is that any difference which is found between backward and normal readers might just as well be the result of the former group's limited experience in reading. But if, as in our design, the two groups have reached the same reading level, and yet the backward readers are worse on a perceptual task, the fact that the two groups have the same reading ability as one another rules out the possibility that the backward readers' perceptual failure is merely the result of a lack of reading experience.

The method which we used in experiment 1 to test the grouping of sounds was to say four monosyllabic words to them. Three of the words had a sound in common which the fourth did not share. The child had to say which was the odd word out. There were three series, each with six trials (18 trials in all). In one series, all four words always had the same middle phoneme, but the last two phonemes were the same in three of the words while the odd one word had a different final phoneme (for example, weed, peel, need, deed). Another series was the same except that the middle phoneme was different in the odd word (for example, nod, red, fed, bed). In the third series, three words had the same opening phoneme while the odd one did not (for example, sun, see, sock, rag). The position of the odd word varied systematically in all three series.

We ensured that all the children understood and could perform the oddity task in practice trials, and we also eliminated forgetting words as a cause of failure, by preliminary trials in which children were given four words at a time and asked to recall them. We discarded two backward readers who consistently failed in these trials; all the others made virtually no memory errors. We took great care to pronounce each word with the same emphasis in order not to give the child any additional cue to the correct word. The experimenter also always hid her mouth from the child's view with a card, so that

Table 1 Details of the two groups

	N	Age Mean	Age Range	IQ (WISC) Mean	IQ (WISC) Range	Reading age (Neale) Mean	Reading age (Neale) Range	Spelling age (Schonell) Mean	Spelling age (Schonell) Range
Backward readers	60	10 yr 4 mth	8 yr 4 mth–13 yr 5 mth	108.7	93–137	7 yr 7 mth	6 yr–9 yr 4 mth	6 yr 10 mth	5 yr–8 yr 9 mth
Normal readers	30	6 yr 10 mth	5 yr 8 mth–8 yr 7 mth	107.9	93–119	7 yr 6 mth	6 yr–9 yr 2 mth	7 yr 2 mth	5 yr 1 mth–10 yr 2 mth

the shape of her mouth would not provide any additional cue for any of the children.

This experiment (Table 2) produced a startling difference between the two groups, the backward readers being markedly worse than the normal group in all three series. Putting the series together, 91.66% of the 60 backward readers made errors and 85% made more than one error. Only 53.33% of the 30 normal readers made any errors and only 26.66% more than one. This difference is all the more remarkable, given that the backward reading group, being older by an average of 3½ years, was actually of a considerably higher intellectual level than the normal reading group. We suggest that many backward readers may be held back by a particular difficulty with organising sounds.

Table 2 Mean error scores (out of 6) in experiment 1

Series	Odd word	Backward readers N 60 Mean	Backward readers s.d.	Normal readers N 30 Mean	Normal readers s.d.
1	Last letter different	1.15	1.43	0.17	1.11
2	Middle letter different	1.49	1.58	0.37	0.99
3	First letter different	2.62	2.26	0.67	1.188

Although the backward readers were worse on all three series (F: 32.499; $d.f.$ 1,88; P <0.001 in an analysis of variance), they were at a particular disadvantage to the normal readers with the series in which three of the four words had the same opening phoneme (F: 4.28; $d.f.$ 2,176; P <0.05). The relationship of this difficulty with the first phoneme to these children's problems with reading and writing should be investigated.

The large size of our groups enabled us to distinguish between those children who made more than one error over the three series and those who made only one error or none at all (Table 3). A clear developmental trend was found among the normal readers, as those who made one or no errors were significantly older and had significantly higher intelligence quotient (IQ) scores, and reading and spelling ages. However no such trend was found among the backward readers; here the only significant difference was that the few children who made one or no errors had a significantly higher spelling age than the rest. This suggests that difficulties in organising sounds may have particularly harmful effects on spelling among backward readers.

We needed further evidence to demonstrate that the large difference between backward and normal readers in categorising sounds was not due to the fact that we sometimes unconsciously emphasised one word more than another, despite our attempts not to do so. This evidence came from experiment 2, with the same children. They were given 10 words spoken successively (dish, car, boat, train, ball, mouse, dog, rake, truck, tent), and asked each time to produce a word which rhymed with each of these words. Here no extraneous cues of emphasis could possibly provide the correct answer.

Again, despite their superior age and overall intellectual ability, the backward readers were by far the worse of the two groups (Table 4), 38.33% of the former group and only 6.66% of the latter failing to produce a rhyming word in one or more trials. This task was probably easier than the earlier oddity test, since in both groups more children succeeded on every trial. But the relative failure of the backward readers in the second experiment is striking confirmation of their difficulty with categorising sounds. Overall, our results strongly suggest that this difficulty could be an important cause of reading failure.

Table 4 Number in each group producing failures in experiment 2

	Total N	No. of failures 0	1	2	3	4	5	6	7	8	9	10
Backward readers	60	37	4	4	4	2	2	2	2	0	0	3
Normal readers	30	28	1	0	0	0	1	0	0	0	0	0

Table 3 Division of the two groups into those making one or no errors and those making more than one error in experiment 1

	Backward readers: One or no errors	Backward readers: More than one error	t test of the difference	Normal readers: One or no errors	Normal readers: More than one error	t test of the difference
N	9	51		22	8	
Mean age	10 yr 6 mth	10 yr 3 mth	0.59 NS	7 yr 1 mth	6 yr 4 mth	2.25*
Mean IQ	112.55	108.06	1.26 NS	109.73	102.87	2.63*
Mean reading age	7 yr 11 mth	7 yr 6 mth	1.51	7 yr 9 mth	6 yr 8 mth	2.91†
Mean spelling age	7 yr 4 mth	6 yr 9 mth	2.05*	7 yr 6 mth	6 yr 4 mth	2.41*

* P <0.05 † P <0.01

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1. Wallach, L., Wallach, M. A., Donier, M. & Kaplan, N. I. *J. educ. Psychol.* 69, 36 (1977).
2. Audley, R. J., *Presidential address to British Association*, Lancaster (1976).
3. Liberman, I. Y. *Bull. Orton. Soc.* 23, 65–77 (1973).
4. Venezky, R. L., Shiloah, Y. & Calfee, R. *Wisconsin Research and Development Center for Cognitive Learning, Technical Report No. 277* (1972).