

division. At passage 4, these fibroblast-like cells (Fig. 1) had modal chromosome number of 54. Fetal cells were used as nuclear donors at passages 4–6. Cells from mammary gland were obtained from a 6-year-old Finn Dorset ewe in the last trimester of pregnancy¹⁸. At passages 3 and 6, the modal chromosome number was 54 and these cells were used as nuclear donors at passage numbers 3–6.

Nuclear transfer was done according to a previous protocol¹. Oocytes were recovered from Scottish Blackface ewes between 28 and 33 h after injection of gonadotropin-releasing hormone (GnRH), and enucleated as soon as possible. They were recovered in calcium- and magnesium-free PBS containing 1% FCS and transferred to calcium-free M2 medium¹⁹ containing 10% FCS at 37°C. Quiescent, diploid donor cells were produced by reducing the concentration of serum in the medium from 10 to 0.5% for 5 days, causing the cells to exit the growth cycle and arrest in G₀. Confirmation that cells had left the cycle was obtained by staining with antiPCNA/cyclin antibody (Immuno Concepts), revealed by a second antibody conjugated with rhodamine (Dakopatts).

Fusion of the donor cell to the enucleated oocyte and activation of the oocyte were induced by the same electrical pulses, between 34 and 36 h after GnRH injection to donor ewes. The majority of reconstructed embryos were cultured in ligated oviducts of sheep as before, but some embryos produced by transfer from embryo-derived cells or fetal fibroblasts were cultured in a chemically defined medium²⁰. Most embryos that developed to morula or blastocyst after 6 days of culture were transferred to recipients and allowed to develop to term (Table 1). One, two or three embryos were transferred to each ewe depending upon the availability of embryos. The effect of cell type upon fusion and development to morula or blastocyst was analysed using the marginal model of Breslow and Clayton²¹. No comparison was possible of development to term as it was not practicable to transfer all embryos developing to a suitable stage for transfer. When too many embryos were available, those having better morphology were selected.

Ultrasound scan was used for pregnancy diagnosis at around day 60 after oestrus and to monitor fetal development thereafter at 2-week intervals. Pregnant recipient ewes were monitored for nutritional status, body condition and signs of EAE, Q fever, border disease, louping ill and toxoplasmosis. As lambing approached, they were under constant observation and a veterinary surgeon called at the onset of parturition. Microsatellite analysis was carried out on DNA from the lambs and recipient ewes using four polymorphic ovine markers²².

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Evidence against a dedicated system for word learning in children

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Children can learn aspects of the meaning of a new word on the basis of only a few incidental exposures and can retain this knowledge for a long period—a process dubbed ‘fast mapping’^{1–8}. It is often maintained that fast mapping is the result of a dedicated language mechanism, but it is possible that this same capacity might apply in domains other than language learning. Here we present two experiments in which three- and four-year-old children and adults were taught a novel name and a novel fact about an object, and were tested on their retention immediately, after a 1-week delay or after a 1-month delay. Our findings show that fast mapping is not limited to word learning, suggesting that the capacity to learn and retain new words is the result of learning and memory abilities that are not specific to language.

In two experiments (study 1 and study 2), 48 three-year-old children (mean age, 3 yr 7 months), 47 four-year-old children (mean age, 4 yr 5 months) and 48 undergraduate students first participated in a training phase that lasted for about twenty minutes. This phase involved the manipulation of ten kinds of objects, four of them familiar (for example, pennies) and six of them novel (see Methods). Subjects were asked to use some of the objects to measure other objects: for instance, they were asked to use pennies to measure the circumference of a plastic disc. Children were told it was a game, and adults were told it was a game designed to teach young children how to measure.

In the course of the training phase, subjects in both study 1 and study 2 were exposed to a new word—‘koba’—used to refer to one of the six unfamiliar kinds of objects. Subjects in study 1 were also taught a new fact about one or more objects belonging to another kind. They were told that the object or objects was given to the experimenter by her uncle. Subjects in study 2 were given information about an unfamiliar object, presented visually. They watched as a sticker was placed on one of the unfamiliar objects, and were told that was where the sticker should go (see Methods).

In each of the studies, one-third of the subjects from each age group were tested for comprehension immediately after the training phase, one-third were tested after a 1-week delay (6–8 days), and one-third after a 1-month delay (28–30 days). Subjects were presented with the original array of ten items and asked to recall which object was the koba. Subjects in study 1 were also asked to recall which object was given to the experimenter by her uncle. Subjects in study 2 were handed a small sticker and instructed to put it where it should go (see Methods).

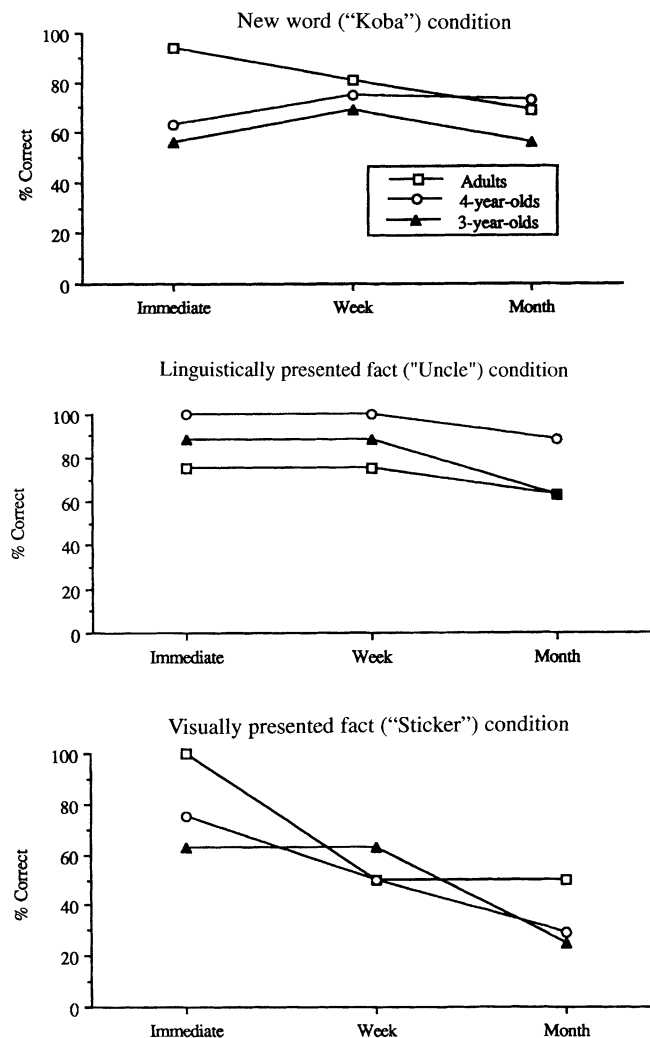


Figure 1 Percentage of subjects who recalled the object to which the novel word referred, the object that had the property of being given to the experimenter by her uncle, and the object that had a sticker affixed to it. 'Koba' condition: Adults were significantly better than both the three- and four-year-olds when tested immediately (adults versus three-year-olds, $\chi^2(1) = 6.0$; adults versus four-year-olds, $\chi^2(1) = 4.6$, both P values of <0.05). Unlike the two conditions below, in which chance performance was calculated as $1/10$ (as there were ten objects), chance performance was calculated as $1/6$, because four of the ten objects were familiar, and children and adults assume that novel words are more likely to correspond to novel objects than to familiar ones¹⁵. As a result, even if subjects forgot which object the new word referred to, they might restrict their guess to the six novel objects. Based on these criteria, all ages performed significantly better than chance in all delay conditions. Also, the 3-year-olds performed significantly better when the new word was presented in the singular rather than in the plural form ($P < 0.01$); this was the only effect of the singular/plural distinction. 'Uncle' condition: All age groups again performed significantly better than chance in all delay conditions. When the three- and four-year-olds were combined into a single group, they did significantly better in the 'Uncle' condition than in the 'Koba' condition when tested immediately ($\chi^2(1) = 6.1$, $P < 0.05$). 'Sticker' condition: Adults did significantly better when tested immediately than when tested after a week and when tested after a month (Fisher's exact tests, $P = 0.04$). the three- and four-year-olds' performance was significantly worse after a one-week delay than it was in the 'Uncle' condition, and significantly worse after a one-month delay than it was in both the 'Koba' and the 'Uncle' conditions. Only the adults performed significantly better than chance after a one month delay; the three- and four-year-olds declined over time, doing significantly worse after a month than when tested immediately (all P values <0.05).

Children and adults successfully learned the novel object to which the label 'koba' referred, and were able to remember the correct word-object mapping after all tested delays (Fig. 1). Adults were significantly better than the three- and four-year-olds when tested immediately, but there were no age differences at the longer intervals, and no significant decline in performance over time by any of the age groups.

Interestingly, however, subjects were equally good at remembering which novel object was 'given to the experimenter by her uncle', suggesting that fast mapping is not special to word learning. In fact, when tested immediately, children did significantly better in this condition than in the word-learning condition. In contrast to the 'koba' and 'uncle' conditions, both children and adults were considerably worse at learning and remembering which object had a sticker affixed to it. All age groups performed significantly better when tested immediately than when tested after a delay. The children performed significantly worse in the 'sticker' condition than in the other two conditions, and only the adults in this condition performed significantly better than chance after a one-month delay; the children's performance after one month was indistinguishable from guessing.

One objection to the conclusion that fast mapping is not special to words is that the 'koba' condition requires subjects to learn and store a novel phonological representation, whereas the 'uncle' condition does not. It is possible that if both tasks involved a novel phonological form, subjects would do significantly worse at the non-word learning task. To test this, 15 three-year-olds (mean age,

3 yr 7 months), 15 four-year-olds (mean age, 4 yr 3 months) and 15 undergraduate students participated in a training phase in which they were taught an arbitrary fact that included an unfamiliar word. Specifically, subjects were taught that one of the unfamiliar kinds of objects 'came from a place called Koba'. They were tested on their memory of the new fact after a 1-month delay by being asked to recall which object 'came from a place called Koba'.

Children and adults performed significantly above chance in this condition, and there were no significant age differences (3-year-olds: 87%; 4-year-olds: 67%; adults: 60%). In fact, after this one-month delay, there were no significant differences between subjects' ability to recall which object 'came from a place called Koba' and their performance in the 'koba' and 'uncle' conditions. The fact that fast mapping still occurred when subjects had to learn a fact that contained a novel word alleviates the concern about task complexity.

In summary, children and adults were as good at learning and remembering an arbitrary linguistically presented fact about an entity as they were at remembering its name, even if the arbitrary fact contained a novel word. Nevertheless, fast mapping does not apply to any arbitrary memorization task, as illustrated by the children who, after a 1-month delay, were unable to recall the location of a sticker. This raises the question of the scope of this process. One possibility is that it applies only to information conveyed through language. Another is that salience is a factor, and that the children and adults simply found the source of the object to be a more interesting fact than the placement of the sticker,

and hence easier to remember. A third possibility is that fast mapping only applies in circumstances in which object identity or object category is considered relevant, as opposed to a property such as location. Nevertheless, although the precise scope of fast mapping remains a topic for further investigation, it is not limited to word learning.

In addition, we found no critical period for fast mapping; there was no advantage for children, at least for the time intervals studied here. In contrast, children are much better at learning phonology, morphology and syntax than adults⁹, consistent with the notion of a biological specialization for these aspects of language^{10,11}. In this regard, then, word learning is different from other aspects of language development. This difference also surfaces in developmental disorders in which word learning is intact but other aspects of language are severely impaired¹², as well as in event-related brain potential studies which find that lexical information is processed differently from grammatical information in both children and adults¹³. The finding that fast mapping is not restricted to word learning is therefore consistent with evidence from different sources which suggests that word learning is mediated by processes of human learning and memory that are not special to the domain of language¹⁴. □

Methods

The novel objects were roughly equal in size and were selected according to the criterion that subjects would be unable to name them. They included a white plastic rectangle consisting of ten plastic bars connected by two longer bars, a grey plastic grid, a wooden stick with a black sponge tip, a trumpet-shaped piece of pasta, a blue plastic tube with a ridged surface, and a brown rubber disc that was smooth on one side and indented with various circles on the other. The familiar objects included pennies, a pencil, a ruler and some string.

For half of the subjects in each study, the new word 'koba' was used in the singular to describe a single object; for the rest, it was used to describe multiple identical objects of that kind. Subjects were told either 'Let's measure the koba. We can count these to see how long the koba is. We can put the koba away now.' or 'Let's use the kobas to measure which is longer. Line up the kobas so we can count them. We can put the kobas away now.'

Subjects who were taught a singular label learned a fact about multiple objects of the same kind, whereas subjects who were taught a plural label for multiple objects of the same kind were taught a fact about a single object. In study 1, subjects were told: 'We can use the thing(s) my uncle gave to me to measure which is longer. My uncle gave these to me. We can put the thing(s) my uncle gave to me away now.' Subjects in study 2 watched as a sticker was placed on one of the unfamiliar objects, and were told: 'Watch where this goes. This goes here [placing the sticker onto one of the objects]. That's where this goes.' The specific objects presented in the different conditions were counterbalanced across subjects.

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A cGMP-gated cation channel in depolarizing photoreceptors of the lizard parietal eye

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Rods and cones of the two vertebrate lateral eyes hyperpolarize when illuminated, a response generated by a cyclic GMP cascade leading to cGMP hydrolysis and consequently the closure of cGMP-gated, non-selective cation channels that are open in darkness^{1–4}. Lizards and other lower vertebrates also have a parietal (third) eye⁵, which contains ciliary photoreceptors that under dark-adapted conditions depolarize to light instead⁶. Depolarizing light responses are characteristic of most invertebrate rhabdomeric photoreceptors, and are thought to involve a phosphoinositide signalling pathway (see, for example, refs 7–9). Surprisingly, we have found in excised membrane patches a cGMP-gated channel that is selectively present at high density on the outer segment (the presumptive light-sensitive part) of the parietal eye photoreceptor. Like the light-activated channel of the cell, it is non-selective among cations. Inositol trisphosphate (InsP₃) had no effect on the same membrane patches. These findings suggest that the photoreceptors of the parietal eye, like rods and cones, use a cGMP cascade and not an InsP₃-mediated pathway for phototransduction, but in this case light increases cGMP. A unifying principle of evolutionary significance emerges: that phototransductions in various ciliary photoreceptors, whether hyperpolarizing or depolarizing, uniformly use a cGMP cascade and a cGMP-gated channel to generate the light response, although there are rich variations in the details.

We recorded under voltage clamp from inside-out membrane patches excised from the outer segments of dissociated parietal-eye photoreceptors of the side-blotched lizard, *Uta stansburiana*. These photoreceptors are remarkably similar to rods and cones in morphology (Fig. 1a). The outer segment of the photoreceptor, like the cone outer segment, is composed of a continuous sheet of convoluted plasma membrane⁵. Bath-applied cGMP elicited a pronounced membrane current from most excised patches (85 out of 120; the rest might have been sealed-off vesicles); cAMP was much less effective (Fig. 1b, c). The current could be activated repeatedly by cyclic nucleotides without ATP, suggesting a direct effect. The blocker *L-cis*-diltiazem inhibited the channel with a half-maximal inhibitory concentration (IC₅₀) of ~3 μM at +60 mV (data not shown). Ca²⁺-calmodulin reduced the current maximally by about 50% by shifting the half-activation constant, K_{1/2} (Fig. 1d). Overall, the channel's activation and modulation properties are similar to those of the rod cGMP-gated channel¹⁰.

The depolarizing response to light of the dark-adapted parietal-eye photoreceptor is associated with an increase in membrane conductance and a reversal potential near zero (ref. 6); thus the phototransducing channel appears non-selective among cations. For the cGMP-gated channel, changing the bath NaCl concentration in our experiments from initially symmetrical NaCl solutions shifted the reversal potential, V_{rev} in a Nernstian manner expected of a cation channel (Fig. 1e). From the respective shift in V_{rev} when all bath Na⁺ was replaced with Li⁺, K⁺, Rb⁺ or Cs⁺ (Fig. 1f), the estimated permeability ratios P_{Li} : P_{Na} : P_K : P_{Rb} : P_{Cs} were 1.23 : 1 : 0.83 : 0.58 : 0.39 (average, 4 experiments). Thus the channel is relatively non-selective among monovalent cations.