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How to cite:

Braisby, Nick; Dockrell, Julie E. and Best, Rachel M. (2001). Children's acquisition of science terms: does fast mapping work? In: Almgren, Margareta; Barreña, Adoni; Ezeizabarrena, María-José; Idiazabal, Itziar and MacWhinney, Brian eds. Research on child language acquisition: proceedings of the 8th Conference of the International Association for the Study of Child Language. Somerville, MA, USA: Cascadilla Press, pp. 1066–1087.

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**Children's Acquisition of Science Terms: Does Fast Mapping
Work?**

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1. Introduction

Children appear to learn the meanings of words with impressive ease and rapidity. Miller (1986) estimates that an average of 10 new words is acquired daily between the ages of one and six years; Templin (1957) estimates that by that age the average child has a 14,000-word vocabulary. Perhaps even more impressive are laboratory investigations of children's word learning. Carey & Bartlett (1978) suggested that children can learn the meanings of new words via a process of 'fast mapping'. Children learning new words have a problem of isolating the word-forms of their language, inferring their potential meanings and then mapping the correct meaning on to the form. The mapping is said to be fast because children appear to achieve this learning on the basis of a limited number of exposures to the use of a novel word and even from just a single exposure (Carey, 1978; Dockrell & Campbell, 1986; Heibeck & Markman, 1987).

There are reasons to believe, however, that such a process ought necessarily to be an extended one, lasting days, weeks or even months. In learning the meaning of a novel word the child has to solve a problem of induction (cf. Chomsky & Fodor, 1980): consistent with the uses of a word that a child has observed, there will be an infinite number of possibilities for its meaning. Without some means of ordering these possibilities and ruling out very many, the child would appear to have no way of settling on the correct meaning. From this perspective, not only must one ask how word learning can occur so rapidly as fast mapping suggests, but also how it can occur at all.

A popular style of explanation for word learning invokes the notion of constraints. The child is assumed to settle on an appropriate hypothesis for a word's meaning through applying constraints on what the meaning is likely to be. The focus of this paper is a core claim of the developmental lexical principle framework (DLPF), a constraints-based framework that attempts purports to explain children's word learning. This claim is that fast mapping is a general mechanism by which children learn the meanings of words. We argue that the DLPF explanation of fast mapping encounters theoretical and methodological difficulties. We report the

results of a substantial study of primary school children's learning of scientific terms, and argue that these are difficult to reconcile with the DLPF. Our position is that either fast mapping explains well a kind of word learning, but that this does not generalise to such naturalistic contexts, or that fast mapping offers at best a partial, and at worst, a misleading view of word learning in general.

1.1. Fast mapping and the Developmental Lexical Principles Framework

In experimental settings, children appear able to acquire substantial information about the meaning of a novel term after a single exposure to its use (Carey, 1978; Dockrell & Campbell, 1986; Heibeck & Markman, 1987). This initial rapid learning was first described by Carey (1978) as a fast mapping. Such rapid learning is difficult to explain given that a single use of a novel word is compatible with an infinite number of possibilities for its meaning. Inferring the correct meaning involves solving this particular induction problem (cf. Chomsky & Fodor, 1980). The problem is quite general. It applies to inferring the general relationship between two variables from a limited number of observations of their values. There will always be an infinite number of such possible relationships consistent with any number of observations. The child's task is similar. She must infer the general (meaning) relationship between the uses of a word and the objects or entities that they pick out, and there will always be an infinite number of such possibilities for any number of uses of the word. Solving the induction problem – learning the meaning of the word – involves being able to order these possibilities, such that classes of possible meanings are ruled out *a priori*.

Despite the difficulty in explaining how children acquire word meanings, in recent years a particular style of explanation has become increasingly popular. It contends that word meanings are learned through applying constraints to the situations in which novel words are first encountered. There have been many candidate constraints proposed to explain different aspects of children's word learning. For example, it has been suggested that children differentiate novel words from or contrast them with existing similar words, and that children generally assume different words have different meanings (Clark, 1987; Elbers, van Loon-Vervoom & van Helden-Lankhaar 1993). Markman (1989) and Clark, (1991) proposed that children assume words refer to whole objects as opposed to parts of objects. Backscheider & Markman (1990) suggested that children assume words refer to categories that lie in taxonomic relations with familiar categories. Mervis, Golinkoff & Bertrand (1994) argued that children assume novel words refer to objects at a privileged 'basic' level. It has been proposed that there is a preference for mapping novel words onto categories of objects that have similar shapes to each other (Imai, Gentner & Uchida, 1994). It has also been suggested that children assume novel words refer to types of object in preference to assuming that they refer

to substances or colour (Baldwin, 1989; Soja, 1992, 1994). These are just some of the constraints that have been proposed. The literature is replete with examples of constraints that children are assumed to apply in word learning situations.

In fact, many of these suggestions, together with two other key proposals for constraints – the constraints of mutual exclusivity (Markman, 1991) and conventionality (Clark, 1991) – have recently been integrated in a developmental lexical principles framework (DLPF) (Golinkoff et al., 1994; Mervis & Bertrand, 1994). Six lexical principles (briefly described in table 1) are assumed to subsume these constraints and guide the child’s word learning.

Principle	Brief Description
Reference	Words refer to elements of the environment
Extendibility	Words may be extended to refer to items similar to previous referents
Object scope	Words refer to whole objects, rather than parts or attributes
Categorical scope	Primary basis for extending word use is the basic level category
Novel name – Nameless category (N3C)	Novel names map to nameless objects
Conventionality	Words refer to what is conventionally taken to be the referent

Table 1. Principles in the DLPF.

According to the DLPF, the first three principles are in place before lexical acquisition begins, and are largely responsible for very early word learning appearing slow and effortful. Subsequent vocabulary acquisition is then governed by the last three principles acting in concert, with the N3C principle playing a central role in explaining fast mapping. The use of N3C is assumed to coincide with the period of later word learning often identified as a point of vocabulary growth, and is intended to explain how such learning appears so rapid and effortless. Fast mapping occurs when the different principles converge on the same hypothesis regarding a term’s meaning.

1.2. Outstanding questions

Though the lexical principles framework represents an impressive synthesis of the constraint-based approaches, it faces both theoretical and methodological difficulties. For example, the notion of novelty that is required to make sense of

principles that refer to novel objects and novel words is generally unexplicated. The issue of the source of the principles is also not generally addressed. Yet the principles can only help resolve difficulties in explaining the acquisition of word meaning provided that questions concerning the ‘acquisition’ of constraints can also be resolved.

More important perhaps are the substantive difficulties that arise in applying the framework to many word-learning situations. Specifically, all of the constraint-based approaches specify that the constraints are subject to *ceteris paribus* restrictions, that is, conditions when the constraints will not apply. Indeed, a child applying the constraints under such conditions will be guided to incorrect conclusions concerning the meaning of novel words. Nelson (1988) notes that the principle of object scope provides no explanation as to how children learn words for actions, attributes or parts. Indeed, were it applied universally, ignoring *ceteris paribus* restrictions, such words could not be learned. Similar remarks apply to the other constraints: indeed, the DLPF does not properly explain the learning of non-taxonomic words, non-basic level words, synonyms, or words with no perceptible referent. The restrictions then signal that there is more to word learning than is revealed by the DLPF. Mervis & Bertrand (1994) concede that the child’s other linguistic and cognitive abilities may “provide a basis for overriding the lexical principles” (p. 1648), but these circumstances are not spelled out, nor are suggestions made as to how, under such circumstances, the child learns words, or indeed what the child learns. Indeed, the DLPF leaves a number of outstanding questions concerning how word learning occurs and what is learned.

According to the DLPF, fast mapping should be optimal when a novel common noun is introduced, where it refers to a basic level within a taxonomy, does not overlap in meaning with familiar nouns, and where the novel word is paired explicitly with a unique, nameless and perceptible object. Indeed, under these circumstances, arguably the DLPF provides a good explanation of word learning. However, it is clear that naturalistic contexts are unlikely to conform to this ideal type. For example, teaching contexts in primary school classes probably only rarely have these specified qualities. In particular, they are likely to lack explicit contrasts (or implicit) contrasts between named and unnamed objects, and between novel and familiar words. In fact, the context and style of presentation of novel words in fast mapping studies is often highly artificial, and, to some extent, presupposes that the child can identify sets of objects as possible referents and distinguishes novel words and objects from familiar ones. Hence, one outstanding question then concerns what is learned, and how word learning proceeds, in more naturalistic contexts such as instruction.

Coupled with this are questions concerning the properties of the novel words themselves, and the ways in which those words are introduced. For instance, fast-mapping studies have largely focused on children’s acquisition of concrete nouns.

Questions then arise concerning acquisition of words with differing syntactic and semantic properties. For example, it may be that other parts of speech (e.g., verbs and adjectives) are subject to different processes of acquisition. Similarly, as research has focused mainly on taxonomic categories, there is a need to consider non-taxonomic domains that lack basic levels. Likewise, there is a need to consider categories which do not necessarily have clear, sharp denotations or perceptible referents.

Other questions arise from the particular methodological choices that have been made in investigations of fast mapping. Children's responses, taken as indicators of their learning, are often restricted to the selection of a target item from a limited set of distracters. Such comprehension tasks are unable to tap the range of ways in which children can put their lexical knowledge to use. Moreover, utility and interpretation of such tasks depend critically on the nature of the distracter items and the contrasts they provide. At best, it is a simple discrimination task, and may not provide a fine-grained view of the child's lexical knowledge. A more thorough assessment is likely to be obtained through the convergence of a number of different measures. Mis-matches between them (cf. Naigles & Gelman, 1995) may suggest that different aspects of learning are being assessed, and can raise questions concerning the most appropriate measure.

The fact that different measures of learning have not often been used also means that it is difficult to determine precisely what is learned as a result of fast mapping. Carey (1978) suggests her results show only that "the children picked up something about the new word" (p. 28), but the wider literature suggests that fast mapping can provide the child with substantial or large amounts of information concerning the meaning of a novel word. This uncertainty is compounded by the possibility that this information might be revised and reorganised before approximating an adult's understanding (cf. Bowerman, 1982; Karmiloff-Smith, 1979). The occurrence of U-shaped curves within language development (Plunkett & Marchman, 1991) and other processes of reorganisation (Shatz, 1985) suggests that assessments of lexical knowledge must be repeated over an extended period of time.

Finally, most studies of fast mapping have focused on children during the initial stages of word learning (e.g., Golinkoff, Mervis & Hirsh-Pasek, 1994) or in the pre-school years (Rice, 1990). Yet the peak rate of vocabulary growth actually occurs during the school years (Nagy & Herman, 1987). Indeed, school entry presumably provides children with the opportunity to acquire a wide range of different novel words, some being specific to particular content domains, and some being domain-general. As Carey (1986, p. 1124) notes, junior and senior high school texts often introduce more new vocabulary per page than do foreign language texts. It could be argued that understanding word learning at this later stage is more critical to explaining word learning in general. Moreover, the purported ease of word learning in fast mapping studies stands in marked contrast to difficulties which exist in the

teaching and acquisition of novel words in the early school curricula. Yet there are important practical implications of understanding word learning in school age children: vocabulary size is strongly correlated with children's overall school achievement (Wells, 1986); school effectiveness studies show the acquisition of skills in the primary school years to be critical for later development (Goldstein & Sammons, 1994).

In sum, there have been few systematic and comprehensive studies of what children learn in fast mapping. It is uncertain as to how closely what is learned approximates the meanings of the terms involved. Few studies have attempted to investigate either the persistence of what the child learns over time or the stability of the child's lexical representations. These difficulties are compounded by the use of limited modes of assessment – often only a standard picture-word matching (comprehension) task is used. The influence of important semantic and linguistic properties of the novel words has not been systematically investigated. Word learning in school age children may differ from, and may be more critical than, the earlier stages of word learning. And fast mapping has been investigated only in highly controlled experimental contexts; notably where there are considerable cues to the meanings of the terms involved.

Our central premise is that what we know of fast mapping is restricted to highly controlled and somewhat artificial situations. We know little of the factors involved in lexical acquisition or of the ways in which lexical representations develop over time. As a consequence, it has been difficult to deepen either our theoretical understanding of fast mapping, or our practical understanding of vocabulary acquisition in contexts of instruction.

2. Rationale

The study reported here was designed to evaluate the DLPF and its claim that children learn the meaning of words through fast mapping. It examines word learning in the more naturalistic contexts of science education and focuses specifically on the role of the key syntactic and semantic properties of the words to be acquired. It employs three different kinds of assessment of the child's lexical knowledge: comprehension, production and draw-and-write. It also assesses children's lexical knowledge immediately after the introduction of novel words and on two occasions up to 6 to 9 months later. The children tested are of two primary school age groups – 4 and 5 year olds and 6 and 7 year olds. The introductions of the novel words, while following as closely as possible the rationale of fast-mapping studies, nonetheless are adapted to conform to a more naturalistic style of presentation. Specifically, the novel words were presented in videos partially constructed from, and designed to match, primary educational science materials. The objective was to determine the influence on word learning of vocabulary knowledge, non-word repetition, word class, semantic domain, domain-specificity

and the time at which acquisition is measured. Via these means we sought to evaluate the viability of constraints framework as a general account of lexical acquisition.

3. Methods

3.1. Participants

284 primary school children between the ages of 4;0 and 7;6, drawn from 9 London primary schools, were recruited to participate in the first experiment. Of these, 30 were unable to participate fully because of illness or moving home, 10 were unable to complete the main testing session, and data from 11 participants were lost due to a computer fault. 233 participants therefore completed the pre- and main-tests of the experiment. Participants were recruited from two age groups: 136 four and five year olds ($n = 136$, mean = 4;8, range 4;0–5;11) and 97 six and seven year olds ($n = 97$, mean = 6;5, range 6;0–7;1).

3.2. Materials

3.2.1. Novel Words

Our objective was to identify 16 novel science terms of very low frequency which would fill gaps in the children's lexicon. Science is an area of the curriculum that plays a central role in the development of children's logical and critical thinking abilities (Harlen, 1985). It is widely viewed as being a difficult subject, both by pupils and primary teachers (Millar, 1991) and children's understanding of science is naturally a major concern for educators. Surprisingly little is known concerning the child's scientific lexicon as they enter school or of its subsequent development. An intensive collection of potential stimulus materials was conducted, with these being subject to further selection according to the following criteria. The national curriculum for science was used to initially identify appropriate subject areas for consideration. From this we identified two taxonomic domains (*animal* and *plant kingdoms*) and two non-taxonomic domains (*electricity* and *astronomy*). Science terms relating to these domains were extracted from children's science texts such as Nuffield Primary Science and more advanced texts such as A-level science texts. Three parts of speech were chosen (nouns, adjectives and verbs) and we tried to ensure that the nouns divided equally into those with observable (i.e., the referent of the term could be directly observed, e.g., *parasite*) and non-observable referents (e.g., *phylum*). Terms were further categorised according to their use in other domains – general (terms used in other domains e.g. *satellite* can be used in both of the domains of space and television) and specific

(terms used in one domain only e.g. *migrate* is specific to the animal kingdom). Following a procedure developed by Dockrell et al. (in press), the novelty of the terms was ensured by a systematic process of identification whereby all words were of extremely low frequency in the Thorndike count of juvenile books, the general Thorndike and Lorges word frequency count, and Kucera and Francis's word frequency count. Ambiguous terms were avoided, as were terms that label subordinate categories, and terms were matched for syllable length (i.e., 2 or 3 syllables). Age of acquisition could not be used as a criterion since none of the words appear in current data sets.

In addition, other criteria relating to apparent conceptual complexity, appropriateness for narrative structure and relation to topics covered in the national curriculum were checked. The best fit for all criteria was achieved with lexical items from the domains of space and the animal kingdom. The 16 target terms for are shown in table 1. These terms were piloted in exchanges with nursery age children at a University nursery. This confirmed that the terms were genuinely novel for the children and were appropriate for learning in a classroom context.

	Domain			
	Animal		Space	
	General	Specific	General	Specific
Non-observable noun	<i>parasite</i>	<i>hominid</i>	<i>googol</i>	<i>apogee</i>
Observable Noun	<i>phylum</i>	<i>mollusc</i>	<i>satellite</i>	<i>tektite</i>
Adjective	<i>camouflaged</i>	<i>ratite</i>	<i>galactic</i>	<i>lunar</i>
Verb	<i>reproduce</i>	<i>Migrate</i>	<i>gravitate</i>	<i>precess</i>

Table 2. The 16 novel words selected

3.2.2. Videos

Four videos were constructed, one for each of the four combinations of domain and domain-specificity. Each video presented four novel words appropriate to that combination. Thus, one video presented four novel domain-general animal words, another presented domain-general space words, another domain-specific animal words, and a fourth domain-specific space words. The videos were carefully constructed so as to retain comparability with similar educational video materials used in primary education and to be of a similar standard to programs the children might watch on television.

The videos were constructed using short segments from educational videos as well as from national broadcasts. Timing of the videos as well as the individual segments they contained was carefully timed, resulting in each lasting approximately 5 minutes. Voice-overs were designed to introduce each novel word in the soundtrack at the same time as a video image of its referent was presented (e.g., apogee was presented with a graphic showing the orbiting earth at its closest to the sun). The voice-overs were scripted with particular care being paid to present implicit linguistic and pictorial contrasts to the target term in a format similar to those used in standard demonstrations of fast mapping. The introductions of the novel words immediately followed two identically scripted introductions involving familiar words. The same structure and duration were adopted for all of the novel words. The scripts were recorded and the resulting videos in a University television and media services department. The videos were then subject to piloting with primary school children. This work demonstrated that the children found it easy to maintain interest and attention, that they found the videos highly enjoyable and that they could learn something of the novel words from these exposures.

3.2.3. Test Materials

The British Picture Vocabulary Scale II, British Ability Scales II (Naming Vocabulary) and the Gathercole Test of Non Word Repetition were used to establish baselines for each child in an initial pre-test.

Comprehension and production tasks were partially computer-administered. Two students from London Guildhall University's Department of Art were paid to draw pictures corresponding to the video images for the novel words and for the contrasting familiar words. Scanned versions of these images then formed the basis of the comprehension and production tasks.

Still images from the videos were also captured and printed, and these formed the basis of a further comprehension task.

3.3. Procedure

Children within each age group were randomly assigned to one of four groups: domain-general animal, domain-general space, domain-specific animal and domain-specific space. These groups were balanced for gender.

Children were assessed individually over four sessions. Within 4 to 8 weeks of an initial pre-test, children were shown one of the four videos and then immediately tested for their comprehension and production of the novel terms (main test). Subsequent to this main-test, children were tested again after 8 to 12 weeks (post-test 1) and again after a further 16 to 24 weeks.

3.3.1. Pre-test

The initial pre-test allowed a baseline assessment of each child's vocabulary and language skills. They were tested using the British Picture Vocabulary Scale II, the British Ability Scales II (naming vocabulary), the Gathercole Test of Non-word Repetition, a draw-and-write task, and a contrast picture comprehension task.

In the draw-and-write task children are told a story and asked to draw and write answers to questions derived from the story. Children were asked to draw a picture of animals and the things that animals do or a picture of space to determine their knowledge of the domains prior to receiving information from the video presentation. Children were asked to label their drawings or tell the experimenter what they had drawn so she could provide labels. Most children spent 2 or 3 minutes drawing their pictures – there was no time limit.

The final task in the pre-test was a comprehension task involving pictures of referents of familiar words, that were used as contrast items in the videos. Children were required to point to the target picture from a choice of 4.

3.3.2. Main-test

In the main-test, children were first introduced to the novel scientific words via presentation of one of the four videos. Children's production and comprehension of the new terms were assessed immediately following the video presentation. For the production task, each child was presented with each of the 4 the artist-drawn images corresponding to the novel words introduced in the video. Children were instructed to tell the experimenter what they thought each picture was or represented. These were preceded by 2 practice items. The comprehension task followed. Each child was presented in turn with the same artist-drawn images, each being accompanied by 3 distracter images. Distracter images were of the following types: image illustrating the same concept within a different domain, a different concept within the same domain, and an irrelevant image from the video. The child was instructed to point to which of the 4 images was named by the novel word. Each child was also given production and comprehension tasks for the novel words presented in another of the four videos, so that each acted as a control for another video group. In fact, the domain-general space group acted as controls for the domain-general animal group (and vice versa), and the domain-specific space group acted as controls for the domain-specific animal group (and vice versa). The domain-general groups also completed a further comprehension task that presented pairs of images appropriate to the novel words. One image was from the same domain as the video and one was from the alternative domain. This task effectively examined how willing the children were to generalise the novel words to domains other than that experienced in the video. For the above production and comprehension tasks

responses were recorded by the experimenter entering an appropriate key press on the computer (e.g., correct, incorrect or don't know); 'response latencies' (i.e., onset of image to experimenter's key press) were also recorded. All children were also given a further comprehension task using images captured directly from the video. For each novel word, three images were presented: the referent identified in the video and images of the two contrasting familiar words. Children were asked to point to the picture named by the novel word. Finally, the comprehension tasks were followed by a draw-and-write task in which children were asked to produce drawings of what they had seen in the video. They were also prompted to provide labels to each element in their drawing. Thus, the task was intended to tap the children's domain knowledge in ways that might reveal learning.

3.3.3. Post-tests

Between 8 and 12 weeks after the main test, these tests were repeated in post-test 1. After a further 16 to 24 weeks, these tests were repeated once more in post-test 2.

3.4. Design

The design is a mixed between-within-subjects design. The between-subject factors are domain-specificity (general or specific), domain (animal or space) and age (4–5 year olds or 6–7 year olds), and the within-subject factors are word type (non-observable noun, observable noun, adjective or verb) and time of testing (main, post-test 1 or post-test 2).

4. Results

The results section addresses the following issues in order: the role of initial vocabulary and non-word repetition in comprehension and production; the factors that influence production; the factors that influence comprehension; the draw-and-write task; and finally evidence of word learning from production and comprehension.

4.1. Initial vocabulary and learning new words

Multiple regressions were performed to examine the relationships between the experimental assessments of comprehension, production and the draw-and-write task at each time of testing, age, and the initial baseline measures (British Picture Vocabulary Scale II, British Ability Scales II (Naming Vocabulary) and the Gathercole Test of Non Word Repetition).

With production as dependent variable, and age and the baseline measures as independent, at each time of testing only age and BAS naming vocabulary contributed significantly to predicting production. At the main test, age ($p < 0.01$) and BAS naming vocabulary ($p = .082$) were predictors ($R^2 = 0.10$; $F(5,227) = 5.06$; $p < 0.001$). At post-test 1, age ($p < 0.05$) and BAS naming vocabulary ($p < 0.05$) were predictors ($R^2 = 0.12$; $F(5,183) = 4.75$; $p < 0.001$). And at post-test 2, age ($p < 0.05$) and BAS naming vocabulary ($p < 0.01$) were again the only significant predictors ($R^2 = 0.19$; $F(5,155) = 7.41$; $p < 0.001$).

Similar regressions were conducted with comprehension at each time of testing as the dependent variable. At each time of testing only age contributed significantly to predicting comprehension. At the main test, age ($p = 0.07$) was a predictor ($R^2 = 0.04$; $F(5,227) = 2.04$; $p = 0.07$). At post-test 1, only age ($p < 0.001$) was a predictor ($R^2 = 0.13$; $F(5,186) = 5.45$; $p < 0.001$). And at post-test 2, age ($p < 0.001$) was again the only significant predictor ($R^2 = 0.10$; $F(5,155) = 3.53$; $p < 0.01$).

Finally regressions were conducted with the results of the draw-and-write task at each time of testing as the dependent variable. At the main test, age ($p < 0.01$), pre-test draw-and-write ($p < 0.001$), BPVS ($p < 0.05$) and BAS naming vocabulary ($p = 0.07$) were all predictors ($R^2 = 0.28$; $F(5,208) = 15.81$; $p < 0.001$). At post-test 1, there were no significant predictors of draw-and-write performance and the model failed to reach significance. However, at post-test 2, age ($p < 0.001$) and pre-test draw-and-write ($p < 0.001$) were the only predictors ($R^2 = 0.36$; $F(5,175) = 19.46$; $p < 0.001$).

The analyses revealed no relationship between the experimental measures and the Gathercole test of non-word repetition. Moreover the BPVS measures of comprehension were also largely unrelated to the experimental measures, showing a very weakly predictive relationship with draw-and-write at the main test. BAS naming vocabulary was a better predictor of performance, particularly of later production. It should be noted that for the experimental measures of production and comprehension of the novel words, only between 4% and 19% of the variance could be explained by the combinations of independent variables.

These results indicate that while both age and naming vocabulary may be related to the learning of novel words in this study, the major proportion of variance in the children's performance needs to be explained by other factors.

4.2. Production

Overall levels of production were low. The children in responding to the target images successfully produced only approximately 1% to 3% of all the novel words. Multivariate ANOVAs were conducted on the aggregate number of productions over all 4 word classes, with the number of productions as dependent variables, and group

(experimental vs. control), domain (taxonomic vs. non-taxonomic) and age (4 and 5 year olds vs. 6 and 7 year olds) as independents.

As expected, the children's age significantly influenced their success on the task (4-5 year olds (0.4%) < 6-7 year olds (3.8%); $F(1,153) = 36.51$, $p < 0.001$) showing that the task is sensitive to developmental changes. A new finding is that the children were more successful with domain general than domain specific items (domain specific words (0.1%) < domain general words (4.2%); $F(1,153) = 54.31$, $p < 0.001$). It may be that, on entry to school, children already have access to some domain-general scientific terms.

Contrary to predictions derived from the fast mapping literature, the children were actually more successful with non-taxonomic words than taxonomic ones (taxonomic (animal) words = 1.3%; non-taxonomic (space) words = 2.9%; $F(1,153) = 16.03$, $p < 0.001$). Children's performance also improved significantly over time (main test (1.3%) = post-test 1 (1.8%) < Post-test 2 (3.4%); $F(1.96, 299.8) = 12.79$, $p < 0.0001$). To assess the impact of word class, scores for each were aggregated over the three times of testing. Other than this modification, an identical ANOVA was conducted to those above. The type of word significantly influenced children's performance (observable nouns (5.6%) > non-observable nouns (2.6%) = attributes (2.7%) > verbs (0.0%); $F(3,459)=30.99$, $p < 0.001$).

4.3. Comprehension

Comprehension for the items was considerably better than for production yet to a large extent the results corroborate those found using production. Multivariate ANOVAs were conducted as before. There was a significant effect of age (4-5 year olds (30.2%) < 6-7 year olds (39.1%); $F(1,153) = 15.27$, $p < 0.001$). A similar pattern was found across the different word types (observable nouns (45.6%) > adjectives (30.4%) = non-observable nouns (33.3%) = verbs (29.4%); $F(3,153) = 19.54$, $p < 0.001$).

There was a trend towards more accurate comprehension in the domain general terms (domain general (36.9%) > domain specific (32.5%); $F(1,153) = 3.65$, $p = 0.06$). Contra predictions from the DLPF, comprehension was also significantly greater for the non-taxonomic items (animal words (29.7%) < space words (39.6%); $F(1,153) = 34.99$, $p < 0.001$). However, in contrast to the production data we found no effect of time.

The results of both the comprehension and production tasks indicate that similar factors are impacting on the children's performance. However, it appears as if production tests the children's performance in the limit, and so arguably may provide a more useful measure.

4.4. Draw and write

A multivariate ANOVA with the number of labels produced in the draw-and-write task as dependents, revealed an increase over the times of testing ($F(3,519) = 24.90, p < 0.001$), an advantage for non-taxonomic domains (taxonomic = 3.4; non-taxonomic = 4.2; $F(1,173) = 12.13, p < 0.01$), differences in age (4 and 5 year olds = 3.2, 6 and 7 year olds = 4.4; $F(1,173) = 2670, p < 0.001$), but no effect of domain-specificity. Although all four video groups defined by domain and domain-specificity showed an increase over time, the domain-general and non-taxonomic groups tended to show the largest increases, as shown in figure 1.

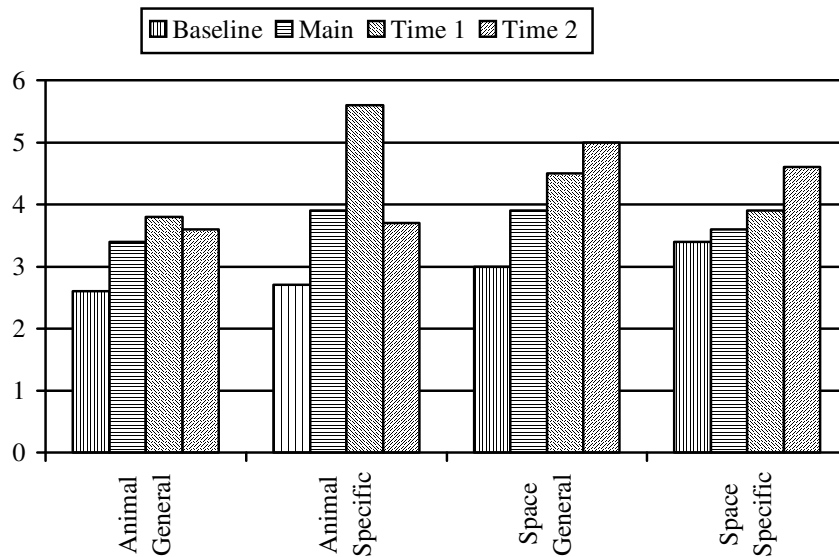


Figure 1. Mean number of different elements in the drawings.

4.5. Word learning

Thus far we have considered the impact of various factors upon production and comprehension, but we have not distinguished between children's performance with words that they were introduced to in the videos and the control words they were also given. This section does so in order to assess more accurately the extent of children's word learning.

4.5.1. Production

Overall there was remarkably little learning, as evidenced by the production task. Differences between control and video groups range from 0.3% to 1.6%, as shown in table 3. These figures confirm that our procedures for selecting stimuli have resulted in science words that the control groups are largely unable to produce. However, on the assumption that a figure of 0% suggests no lexical knowledge and a figure of 100% reflects relatively complete lexical knowledge, perfect learning of the novel words would be demonstrated by a difference between groups of the order of 100%. Although learning has taken place, the size of differences we have found indicate that very little learning has occurred. Nonetheless, groups witnessing the a video performed better on the novel words it contained than did control groups ($F(1,153) = 5.72, p < 0.05$). The domain of the words influenced this word learning. However, contrary to what would be predicted from DLPF, there was learning only for non-taxonomic space words ($p=0.06$).

Group	Domain of the words	
	Animal	Space
Experimental Group	1.5%	3.7%
Control Group	1.2%	2.1%

Table 3. Differences between video and control groups in production, as a function of the domain of the words to be produced.

Domain-specificity also affects learning: there is evidence of learning only for domain-general words ($F(1,153) = 4.169, p < 0.05$) and only for domain general space words ($p=0.05$), as shown in figure 2.

4.5.2. Comprehension

The comprehension task provides evidence of learning ($F(1,153) = 22.92, p < 0.001$) for both animal ($p < 0.01$) and for space words ($p < 0.01$). The size of learning is greater than suggested by the production task. On the assumption that successful performance in the forced-choice comprehension task can be expected on 25% of trials by chance alone, perfect learning would be suggested by a difference between groups of the order of 75%. The extent of learning suggested by the comprehension task ranges from 7.4% to 8.4%. These results are shown in table 4.

Group	Domain of the words	
	Animal	Space
Video Group	33.4%	43.9%
Control Group	26.0%	35.3%

Table 4. Differences between video and control groups in comprehension, as a function of the domain of the words to be comprehended.

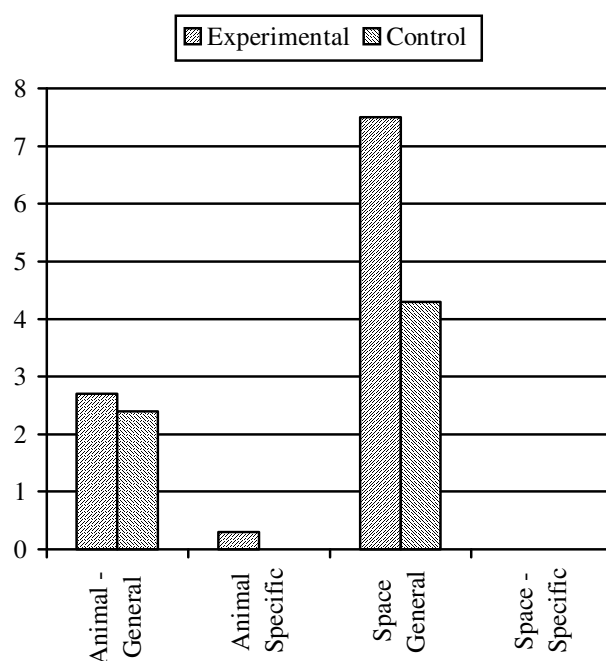


Figure 2. Proportions of successful productions of the novel words by domain and domain-specificity

Again we find similar patterns between comprehension and production. Learning is also influenced by the domain specificity of the words learned and the type of word ($F(3,153) = 4.71, p < 0.01$), with learning for domain general space words ($p=0.06$), domain general animal words (0.001), domain specific space words (0.05) but not for domain specific animal words, as shown in figure 4.

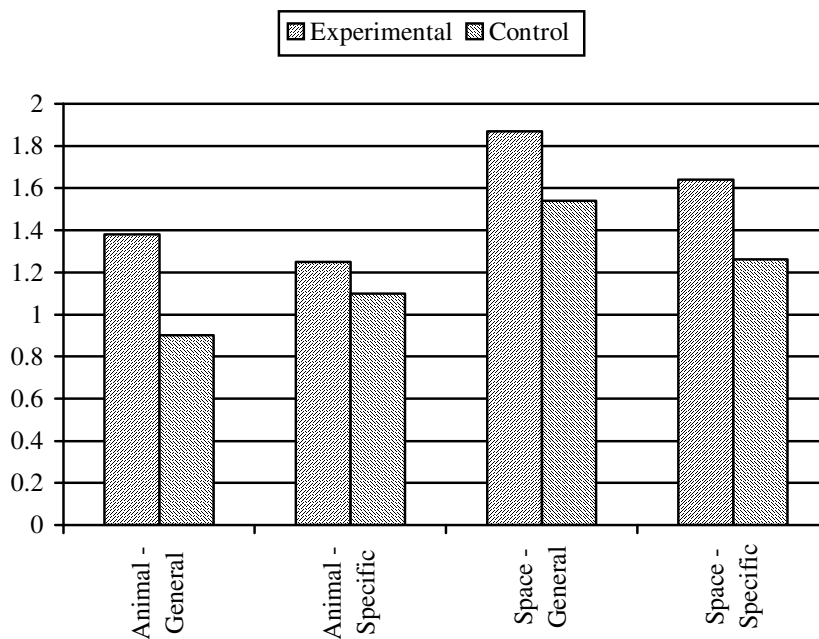


Figure 3. Proportions of correct comprehension responses by experimental group

4.6. Summary Of Results

In sum, the results show that children's production of the novel words may be linked to their baseline naming vocabulary, but is relatively unrelated to their baseline comprehension or phonological skills (as measured by non-word repetition). There is evidence that semantic factors (such as type of domain and the domain-specificity of novel words) play an important role both in comprehension and production overall, but also, and more specifically, in word learning. Our findings show that word class has a substantial impact upon word learning, with

observable nouns being produced more than other types of word. However, predictions from the DLPPF have not been borne out. Word learning, in general, is very poor, contrary to the majority of fast-mapping studies. Moreover, the influence of domain runs counter to the predictions of DLPPF: words from non-taxonomic domains, which cannot be linked to basic level categories, are learned better than words from taxonomic domains. There are also influences of time of testing. Production of the novel words increased over the 6 to 9 months from the initial introduction to the final post-test. This supports the suggestion that children's lexical knowledge changes over time, and that the result of fast mapping is not a stable, mature and complete specification of a word's meaning. Finally, the draw-and-write task suggests that the children gained more information than purely lexical knowledge from the video presentations, and that this too changed over time.

5. Discussion

There are three important features of the results of this study: the disparity between production and comprehension, the differential performance between control and experimental groups and the significant role of semantic and syntactic factors.

The most striking finding was a substantial disparity between the children's ability to produce the novel words on the one hand and their ability to comprehend them on the other. Most previous experimental investigations of word learning and vocabulary assessments have focused on comprehension measures, the assumption being that these accurately reflect lexical knowledge. Our results challenge this assumption. They highlight the need to provide children with the opportunity to use new words in different contexts. More specifically our findings raise an important question as to the criteria to be employed in determining the extent of children's lexical knowledge both in assessments and classroom contexts. If production is used, our evidence is that children have learned little of the novel words. If comprehension is used, then the children appear to have learned rather more. Comprehension tasks may be appropriate to reveal learning if the foils are very carefully chosen, but that this is by no means guaranteed. Indeed, it may be that comprehension tasks are susceptible to irrelevant response strategies as well as the child's inability to exclude alternative choice items.

It may be that there are different levels of word learning and correspondingly different levels at which it can be assessed. The marked differences between comprehension and production measures are consistent with a picture of word learning in which comprehension measures provide a weak indication of learning. They may also be susceptible to the influences of children's general strategies and knowledge to the degree that they provide highly structured forms of assessment. Production, by contrast, is a less structured form of assessment, and requires the

child to provide the connection between their knowledge and the appropriate lexical item. In sum, these different modes of assessment suggest that it may be fruitful to distinguish between learning and understanding. Much of the literature on word learning has focused exclusively on learning, and has not been concerned to consider the child's understanding of the word learned. Our evidence suggests that the two are intertwined, with the level of the child's understanding perhaps influencing the extent of their learning.

The second aspect of our results concerns the use of control groups. In many previous studies of children's word learning it has been assumed that control groups are unnecessary since children who are not exposed to the novel words are assumed to be unable to produce or comprehend those words. Having established the very low frequency of the novel words, our evidence suggests that even children who are not exposed to these words can nonetheless succeed in comprehension tasks. It appears that a range of factors, including non-lexical ones, govern success in such tasks. Thus, learning may only be properly assessed by comparing learning groups and control groups or by comparing individual children's performance with novel and control words.

Finally there was strong evidence supporting our predictions pertaining to word class. Observable nouns were produced and comprehended significantly better than the other types of word. Such a result highlights the difficulties in acquiring terms that relate to scientific processes or activities, despite the use of video, which allows for the depiction of action. The Developmental Lexical Principles Framework (DLPF) suggests that word learning should be best supported for nouns and for the introductions that pair explicitly novel words with nameless objects. Our results confirm that nouns tend to produce better word learning, but this result is qualified: nouns with non-observable referents are in fact learned only as well as adjectives. Additionally, word learning for verbs is particularly poor. The difference in learning for verbs, non-observable nouns and adjectives is not readily explicable according to the DLPF.

Children appear able to learn some aspects of a novel word's meaning when the word is introduced in a fast mapping format within the classroom. Children may learn enough of the novel word's meaning to distinguish its referent from alternatives with which they are familiar. However, the learning is, in general, insufficient to distinguish the novel word's referent from similar alternatives, or from alternatives from the same domain. The partial information that is learned appears to be retained over several months, but the advantage shown by the novel word over control words (matched words that were not introduced to the children) reduces over this period. In general, the learning is also insufficient to support the child's production of the new word even in appropriate contexts. Children may learn to draw successfully certain inferences about the novel word's meaning, but also may draw other inferences in error.

Our findings suggest that word learning is not particularly subject to developmental influences even though age does influence the amount of success a child can demonstrate in production and comprehension measures. Overall, older children perform better with these measures, but we have found no evidence that they are better able to learn the meanings of new words than the younger children. Other subject factors include the baseline measures of language ability (British Picture Vocabulary Scale II, British Ability Scales II, and the Gathercole Test of Non-word Repetition) and the draw-and-write task. Although, the phonological skills implicated in working memory have been thought to be key in vocabulary acquisition, our evidence does not support this view. Success in production was reliably associated with baseline naming vocabulary and age only. Comprehension was unreliably associated with age and no other baseline measures. Even these associations, however, never explained more than 22% of variance.

The strongest influences on word learning appear to derive from the semantic and syntactic properties of the words themselves. Domain general nouns with observable referents, and from non-taxonomic domains, produce the greatest evidence of learning. Word learning for words from the non-taxonomic domain of space is better than for the taxonomic domain of the animal kingdom, contra the predictions of the DLPPF. Word learning is also better for domain-general than domain-specific words, a finding that is not readily explicable according to the DLPPF. One interpretation of these findings, however, is that successful word learning relies upon existing knowledge to organise and assimilate the novel word's meaning. Domain general words are more likely to possess more links to existing knowledge and so are more readily learned. Taxonomic words are not learned well in general, possibly indicating that where the child possesses relatively rich domain knowledge (e.g., animal kingdom) particular care must be taken to provide the links to their existing knowledge. By contrast, where children possess relatively sparse domain knowledge (e.g., space), the links to existing knowledge may be less important. In sum, our evidence points to the child's existing knowledge base playing a significant role in word learning.

6. Conclusions

This study suggests that fast mapping does not in general occur within the naturalistic contexts of word learning typically found within primary education. Even though the video presentations were designed to preserve the implicit and explicit contrasts found within fast-mapping studies, we found relatively little evidence of word learning. This raises methodological as well as theoretical issues. Many fast mapping studies have not incorporated control groups into their design as we have. Most have used nonsense words instead of real, very low frequency words. Often the semantic and syntactic properties of the words have not been

carefully controlled. However, it is likely that children approach science lessons, and so the materials we have used, differently from a more artificial-seeming experiment. It may also be that fast mapping is less efficacious when the word learner is attempting to integrate the new word with existing knowledge. These issues go well beyond the immediate focus of this paper. We can conclude, however, that the account of fast mapping provided by the DLPF may explicate well children's *capabilities* for learning novel words, but poorly explains how children in fact learn words, such as science terms, that are introduced in classroom contexts. It may be that fast mapping provides a good explanation of one type of word learning, a type that is not normally found outside the laboratory. Alternatively, fast mapping may support the very initial stages of word learning, but is at best a partial and at worst a misleading view of word learning in general.

Endnotes

* We gratefully acknowledge the support of The Leverhulme Trust for funding this work, the staff at London Guildhall University who helped with the construction of the video materials, and the teachers and pupils of the schools who participated in this research.

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