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## **Multiple cues in language acquisition**

### **Poverty of the stimulus and multiple cue approaches**

The “poverty of the stimulus” argument has been central to debates over the nature of language acquisition. The poverty of the stimulus, originally articulated by Chomsky, contends that the language to which a child is exposed does not contain sufficient information to account for children’s ability to acquire language, because there are an indefinite number of possible grammars that are consistent with the child’s experience of the language. A consequence of this argument is that language-specific, innate constraints are necessary to explain language development. An alternative perspective is in the empiricist tradition, whereby general-purpose learning mechanisms are seen to be sufficient for learning. Poverty of the stimulus, then, is viewed as mistaken because it underestimates the general-purpose learning mechanisms or because it underestimates the constraints available in the child’s language environment.

Studies of multiple cues have emerged as a primary argument instead for the richness of the stimulus, and have proceeded by demonstrating the presence and informativeness of multiple cues in children’s language environment, and also through testing children’s sensitivity to these simultaneously available sources of information. Proponents of multiple cues suggest that the poverty of the stimulus argument is valid only when only a single aspect of language input is considered, but when multiple sources are taken into account, the task of language acquisition is substantially simplified due to multiple constraints each introduced from distinct, interacting sources of information.

### **Multiple cues for speech segmentation**

Multiple cues for language acquisition have been discussed at numerous levels of language structure. Identifying words in continuous speech is a substantially difficult task facing the child, because even in child-directed speech there are no reliable pauses between words, and the speech stream is presented against a background of noise. Consequently, numerous information sources have been proposed to assist the child in solving this task. In a now-famous series of studies, J. Saffran and colleagues showed that transitional statistical information between syllables in continuous speech was used by children in determining word boundaries. Allophonic variation (different realisation of phonemes at word edges compared to word medial segments), phonotactic constraints (certain phoneme transitions usually occur within words, and others tend to occur between words), and prosodic information (stress position and syllable lengthening) have also been shown to contribute to segmentation performance. Studies of the prevalence of cues in natural language for speech segmentation have shown that single cues are at best partial in their ability to indicate word boundaries, so multiple cues are required in order to identify word boundaries to a useful level of accuracy.

### **Multiple cues and learning word meanings**

Another domain of language acquisition where multiple cues are vital is forming mappings between words and their referents in the environment. How children determine which aspects of the environment are being referred to by words in the language – the so-called “Gavagai” problem of the indeterminacy of translation, posed by the philosopher Quine in 1960 – appears to be intractable when the complexity of the utterance, the environment, and the social pragmatics of the speech act

are taken into consideration. Yet, multiple cues can assist in resolving this mapping problem by contributing constraints. For instance, cross-situational statistics provide information about the intended referent, where particular words and particular referents tend to co-occur across multiple learning situations, even if from a single learning situation it would be impossible to constrain the word-referent mapping sufficiently. Artificial language studies, that implant cross-situational statistics for acquisition of word-object mappings, show that learners are able to utilise cross-situational statistics to learn the intended meaning of a word.

However, co-occurrence statistics are frequently inaccurate. Children often hear the word “read” in the presence of a book, yet they must learn that this correspondence is functional rather than referential. Function words also co-occur frequently with objects and actions in the environment, thus, the child must also learn that “the” is not the label for a book. Multiple cues assist in the process. Distributional information within the utterance determining the grammatical role of words in the utterance, constrains the possibilities for mapping multiple words onto referents in the environment (words following “the” are likely to refer to objects, words following “you” are likely to refer to actions). Artificial language learning studies and computational models of cross-situational learning demonstrate that including such distributional cues to grammatical roles in utterances improved word learning compared to when distributional cues were absent from utterances.

### **Multiple cues to grammatical categories**

These previous studies have shown that multiple cues within the language constrain the range of possible mappings considered by the learner and facilitate language acquisition. A variety of other cues have also been noted as useful for constraining the range of possible referents that children may consider, by directing their attention to the intended referent. Social cues (pointing with a finger or eye-gaze direction) have been shown to be critical for acquisition of word-object mappings. In a series of studies, R. Wu, N. Kirkham and colleagues have investigated how such cues combine in constraining attention for word learning. In these studies, social cues directed infants to spatial locations where objects and sounds co-occurred. Early in development (4 months) infants learned the spatial locations from social cues but did not learn the referents associated with each sound. By 8 months, social cues were used in combination with sound and vision to form the mappings. Without the social cues, learning was substantially reduced. In related studies, multiple cues from sound and vision were necessary for infants to learn to predict sequences of shapes. Without the presence of multiple cues, infants failed to acquire the statistical structure of the sequences.

Poverty of the stimulus arguments have not been used to characterise the difficult tasks of speech segmentation or word-to-world mappings, because it is understood that the types of information used to resolve these tasks are necessarily dependent upon language experience. However, the traditional stamping ground for the poverty of the stimulus debate has been over grammatical category learning and, relatedly, syntax acquisition. From the child’s exposure to the language, it is claimed that grammatical categories and their dependencies in syntactic structure cannot be accurately acquired. There is a consensus that grammatical categories can be to a certain degree distinguished in terms of their usage in sentential contexts, though these categories are not perfectly reflected by their distributional patterns. In a seminal paper, M. Redington and colleagues demonstrated the power of distributions of words for reflecting words’ grammatical categories. Using the co-occurrence of two words before and after, words could be clustered together in terms of grammatical category. These clusters respected grammatical category distinctions between nouns, verbs, adjectives, and adverbs, but also nuanced distinctions within each category, such as animate versus inanimate nouns, or transitive versus intransitive verbs. Such work has since progressed to

determine exactly what contexts are most accurate for reflecting grammatical categories, and, in tandem, what contextual information children are able to utilise for category acquisition. As in the other domains of language acquisition, using a single cue – in this case, distributional information – results in accurate, but not perfect, classification of words into grammatical categories. However, additional information regarding the phonological information of words can improve categorisation further.

Morphology is an obvious candidate for phonological information reflecting grammatical categories, as it provides a direct correspondence between the grammatical category of a word and its phonological expression. In English, for instance, the suffixes –ing or –ed are frequently attached to verbs, but only rarely to nouns (i.e., most often resulting in a gerund). Languages other than English, with richer morphological systems, will contain greater abundance of phonological information about grammatical categories. Yet, more subtle phonological information also provides information about a word's grammatical category. M. Kelly first demonstrated that grammatical categories of words were distinct in terms of segmental and prosodic phonological cue distributions. In English, for instance, nouns are more likely to contain nasals and low vowels and have first syllable stress than verbs. In French, as another instance, nouns tend to contain more plosives and fewer reduced vowels than verbs. Individual phonological cues to grammatical category are language-specific, but their presence appears to be a language universal: they have been demonstrated as marking grammatical categories with high statistical significance in dialects from Altaic, Indo-European, Japonic, and Sino-Tibetan language families.

### **Interaction of cues**

How cues interact is a key issue in explaining the role of multiple cues in language acquisition. In terms of grammatical category learning, the sources of information for marking categories are largely complementary. Across the world's languages, there is an inverse relationship between the richness of morphological information and the extent to which word order is constrained. For free word order languages, the syntactic role of a word tends to be indicated by morphology, whereas for languages with fixed word order, the syntactic role is reflected in relative position in the sentence and such languages tend to have depleted morphological systems. Thus, grammatical category information is stored to varying degrees in distributional or morpho-phonological information across languages. Within a language, there is also evidence of interactivity between different cue types. For nouns, distributional information provides rich and reliable information about category membership, whereas verbs tend to occur in more variable contexts, such that distributional information more weakly defines category membership. However, phonological information is a stronger cue for indicating the verb category than the noun category. Indeed, children appear to rely more on phonological cues when guessing the referent for actions (verbs) but not objects (nouns). For both grammatical categories, both distributional and phonological information is valuable and important, but the relative value of each stands in a serendipitous relationship, in terms of cue availability to assist in language acquisition, an observation that is consistent across languages.

One outstanding question in multiple cue use is how cues interact for learning. S. Mattys and collaborators proposed a hierarchical model for multiple cues operating in speech segmentation, whereby allophonic and phonetic information is only used to indicate word boundaries if lexical information is unavailable to the listener, and prosodic information, such as stress or speech rhythm is only used when finer-grained phonetic information is unavailable. Such a theoretical model is consistent with data from the changing dominance of statistical and stress cues with age for speech segmentation: older children learn to over-ride general transitional information with abstracted

knowledge about the distributions of cues in their language. An alternative view is that all cues operate simultaneously, contributing cumulatively to identification of the language structure, and that even redundancy across cues may be required for learning as in the intersensory redundancy hypothesis, where multiple overlapping cues assisted children to learn auditory and visual perceptual discrimination. Such models require weighting of cues, according to their relevance to the current situation, or their general utility in indicating the structure of a particular aspect of language learning – whether it is identifying words from continuous speech, forming word-to-world mappings, or determining grammatical categories within the language. Yet, such cue weighting can be conceived as being formed from information in the environment alone, by the learner detecting second-order structural relations across cues – i.e., conditional probabilities that are not present in the statistical patterns for each cue individually. Computational models of acquisition of grammatical categories, for instance, have shown how multiple cues can facilitate the tasks of grammatical categorisation when considered interactively, but comparable models of hierarchical cue use have not yet been explicitly tested. Analogous models of multiple cue use in other domains, such as depth perception in visual processing, currently favour models of relative weighting of cues in simultaneous operation. Such models of perception draw on both innate and acquired constraints to assist in visual processing, however models of language acquisition are not yet in a position to specify the relative contributions of internal and external structure for learning.

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See Also: Cross-situational word learning; Grammatical categories (acquisition of); Poverty of the stimulus argument / 'logical problem of language acquisition'; Word segmentation; Word-to-world mapping

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