See Also: Bruner, Jerome; Child-Directed Speech (Features of); Conversational Implicature; Conversational Skills; Discourse-Pragmatics; Evidential Markers; Humor; Joint Attention and Language Development; Narrative Development; Nonliteral Language Use; Perspective Taking in Communication; Recasts, Clarifications, and Other Indirect Negative Evidence; Speech Acts.

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Prediction in Language Learning, Role of

Predictive language processing is the activation of upcoming linguistic input before it is encountered by the language user. Such pre-activation may arise from various information sources and mechanisms such as simple associations, statistical learning, or priming mechanisms but also from more active forecasting mechanisms. Theories about the role of prediction in language learning differ in their emphasis on experience-based mechanisms, on the role of the language production system, and the importance of inferential and context-dependent mechanisms relying on discourse and event information. Experimental evidence in support of each of these three major approaches has been collected, which suggests that only a combination of these mechanisms can account for all facets of prediction in language learning. Effects of literacy on language-mediated prediction suggest that prediction not only plays an important role for learning but also that increased language experience enhances predictive language processing. Traditionally, prediction has been thought to play only a minor role during language understanding because of the vast possibilities available to the comprehender as each upcoming word is encountered. However, the accumulation of experimental evidence for the anticipation of linguistic and nonlinguistic input over recent years has led to suggestions that prediction is a fundamental characteristic of the functioning of the human mind in general and of language processing in particular.

Experience-Based Approaches

Many approaches to predictive processing rely heavily on the experience accumulated by language users. Connectionist models such as simple recurrent networks, for instance, have been used to simulate language learning. Predictive processing, using association-based learning principles, is a key characteristic of such models. According to J. L. Elman, such networks can learn to make predictions by approximating the conditional probabilities of succeeding chunks. Information about distributional constraints on the context in which particular chunks occur causes the recurrent network to learn representations that correspond to syntactic and semantic categories. Moreover, recurrent networks are able to encode long-distance dependencies (e.g., the dependencies that occur in wh– questions and relative clauses) and to generalize to novel instances. Recurrent networks thus detect predictive dependencies, and learning occurs as a consequence.

A related approach has been suggested by S. McCauley and M. H. Christiansen. They view language production and comprehension as a single system that is based on a single set of statistical information and representations. Syntactic knowledge is assumed to build up steadily through abstraction over multi-word sequences. Transitional probabilities are used to chunk words together as incoming utterances unfold. These stored sequences are thought to underlie both comprehension and production. The distributional information embedded in the chunks employed during production is used to predict upcoming language input during comprehension.

In general, statistical learning approaches of predictive language processing focus on the notion that language learners are skillful in detecting statistical relationships in the input. Evidence for this comes from a study by J. R. Saffran, R. N. Aslin, and E. L. Newport. They presented 8-month-olds with a continuous spoken sequence of multisyllabic words from a nonsense language (i.e., *golabupabikututibubabupugolabubabupu*). The only cues that could be used to segment the words and detect word boundaries were the statistical properties of the syllables in the sequence. The 8-month-olds were found to be able to discriminate words such as *golabu* and *pabiku* from sequences that crossed word boundaries, such as *bupabi*. Thus, 8-month-olds were observed to detect boundaries of spoken words without obvious acoustic cues. Similarly, with regard to syntax, J. R. Saffran argues that predictive dependencies (e.g., that *the* or *a* is usually followed by a noun) allow language learners to acquire abstract structure. Dependencies in linguistic phrase structure are thought to be detected by the learner and used to establish word sequences that cluster into phrases. Such a learning process then leads to a modulation of subsequent analyses resulting in the accentuation of syntactic relations within phrases as well as dependencies between phrases.

Language learning therefore appears to be at least to some extent a consequence of predictive processing. A study by R. K. Mishra, N. Singh, A. Pandey, and F. Huettig suggests that the converse may also occur: Prediction may be a direct consequence of learning. In their study, Indian adults with either very low or high proficiency in reading were presented with simple spoken sentences containing the name of a target object (e.g., *door*) while they were looking at a visual display containing the target object (the door) and three unrelated objects. The spoken sentences were constructed so that participants could use semantic, syntactic, and associative information to predict the target object. High literates but not low literates showed anticipatory eye movements to the target object. These data suggest that literacy is an important mediating factor for the fine-tuning of anticipatory mechanisms. Consistent with this notion are findings by A. Borovsky, J. L. Elman, and A. Fernald, who observed that children age 3 to 10 with relatively high vocabulary knowledge were faster to anticipate target words than children with lower vocabulary knowledge. Literacy thus may be a proxy for experience. Better readers have more experience with written language, and reading, in turn, supports experience-based mechanisms such as word associations or featural restrictions that narrow down the possibilities for upcoming input.

Production-Based Approaches

Other approaches to predictive language processing ascribe a major role to the language production system. Language learning is a direct consequence of predictive language processing, according to F. Chang, G. Dell, and K. Bock. Their dual-path model includes a meaning system and a sequencing system that converge on a word output layer to ensure the right timing of the production of words consistent with the intended message. The meaning system involves the binding of concepts and event roles and may be related to the spatial system (similar to the *what* and *where* systems in vision), which is consistent with observed strong links between spatial and language processing. The sequencing system is an error-based learning mechanism. Syntactic abstractions needed for the production of sentences are thought to arise from learners' predictions about upcoming words. Learning occurs when the model's production-based predictions are compared against utterances generated by others. Prediction error will result in adjustments to the system that generated the predictions.

Pickering and Garrod also assume that much of predictive language processing involves information used during language production. They suggest that listeners use forward production models and covertly imitate speakers to predict the speaker's upcoming utterances. These predictions by simulation are assumed to be impoverished representations rather than fully implemented production representations. Prediction by simulation, they argue, is complemented by an association route, which estimates the probability of a word being uttered based on the language user's experience of speakers' utterances.

M. J. Pickering and S. Garrod proposed that prediction by association may play a more important role than prediction by simulation, when comprehenders and producers are quite different (i.e., when an adult and a child converse). N. Mani and F. Huettig presented evidence that the language production system is indeed involved in the mechanisms underlying prediction in language comprehension. In their study, 2-year-olds heard sentences spoken by an adult speaker, such as *The boy eats a big cake* or *The boy sees a big cake*, while looking at two-object displays (e.g., a cake and a bird). The average 2-year-old anticipated and looked at the

target object before it was mentioned when the sentence contained the semantically constraining verb (*eats*), but not when it contained the neutral verb (*sees*). Crucially, toddlers' anticipatory eye movements were significantly correlated with their productive vocabulary size. Children with large production vocabularies but not children with small production vocabularies showed evidence for prediction. This finding suggests that production-based prediction mechanisms are already important in early development.

Discourse and Event-Based Approaches

Knowledge about events is also thought to be an important characteristic of predictive processing because events tend to reoccur and show regularities and thus are likely to be an important organizing principle of past experience. R. Metusalem, M. Kutas, T. P. Urbach, M. Hare, K. McRae., and J. L. Elman investigated whether event knowledge is immediately accessible during online language processing and a major determinant of predictive language processing. Adult participants read three-sentence passages that described typical events (e.g., *A huge blizzard ripped through town last night. My kids ended up getting the day off from school. They spent the whole day outside building a big snowman/jacket/towel in the front yard.*). Contextually anomalous words related to the described event, such as *jacket*, elicited a reduced event-related brain potential (ERP) N400 amplitude compared to equally anomalous words that were unrelated to the described event (e.g., *towel*). Additional experiments and analyses of the data suggested that the effect was not due to simple priming or word associations (i.e., between *blizzard* and *jacket*). The authors took these findings to argue that discourse information and event knowledge are likely to drive anticipatory processing.

A study conducted by A. Kukona, S.-Y. Fang, K. A. Aicher, H. Chen, and J. S. Magnuson directly contrasted the effect of local priming with the effect of event-based sentence context on anticipation of upcoming input. Their participants heard active (subject–verb–object) sentences that included verbs such as *arrest* (*Toby arrests the crook*) while they were looking at visual scenes that included verb-related agents (e.g., a policeman) and patients (e.g., a crook). Participants showed anticipatory fixations to both agents (the policeman) and patients (the crook), although the agent role had already been filled (*Toby*). In other words, they observed effects of simple priming (arrest–policeman), although it conflicted with event knowledge (namely, that typically crooks get arrested and not policemen). Findings such as these suggest that multiple mechanism accounts are required to provide a complete picture of the pre-activation of (potentially) upcoming linguistic input. The respective contributions of the multiple mechanisms for anticipatory processing in general and the role of these mechanisms for language learning in particular remain to be determined. For instance, it is likely that the importance of particular mechanisms driving predictive processing during language learning depends on the particular linguistic or situational context.

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See Also: Alignment (Interactive); Associative Processes; Auditory Sequence/Artificial Grammar Learning; Bayesian Inference in Word Learning; Chunk-Based Language Acquisition; Connectionist Models of Language Development; Distributional Knowledge and Language Learning; Event Perception and Language Development; Literacy Effects on Cognitive Development; Statistical Learning.

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