(eds) *Language Perspectives: Acquisition, Retardation, and Intervention*. Baltimore: University Park Press.
Nelson K (1974) Concept, word, and sentence: interrelations in acquisition and development. *Psychology Review* **81**: 267–285.
Owens RE (1996) *Language Development: An Introduction*. Needham Heights: Allyn and Bacon.
Rice ML (1984) Cognitive aspects of communicative development. In: Schiefelbusch R and Pickar J (eds) *The Acquisition of Communicative Competence*. Baltimore: University Park Press.
Wells G (1985) *Language Development in the Preschool Years*. New York: Cambridge University Press.

Further Reading

McLean J and Snyder-McLean L (1999) *How Children Learn Language*. San Diego, CA: Singular Publishing Group.
Naremore RC and Hopper R (1990) Development of meaning. In: Naremore RC and Hopper R (eds) *Children Learning Language: A Practical Introduction to Communication Development*, pp. 71–82. New York, NY: Harper and Row.
Olah LN (2000) How language comes to children: from birth to two years/how children learn the meaning of words. *Harvard Educational Review* **70**: 538–543.
Owens RE (1999) Specific intervention techniques. In: Owens RE (ed.) *Language Disorders: A Functional Approach to Assessment and Intervention*, pp. 302–309. Needham Heights, MA: Allyn and Bacon.
Owens RE (2001) Preschool pragmatic and semantic development. In: Owens RE (ed.) *Language Development: An Introduction*, pp. 292–302. Needham Heights, MA: Allyn and Bacon.
Rhea P (2001) *Language Disorders from Infancy through Adolescence*. St Louis, MO: Mosby.
Wilde J, Astington JW and Barriault T (2001) Children's theory of mind: how young children come to understand that people have thoughts and feelings. *Infants and Young Children* **13**: 1–12.

Lexical Ambiguity Resolution

Intermediate article

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CONTENTS

Most words have several meanings, yet readers and listeners are able to determine a writer's or speaker's intent from the word's context. Research on the resolution of lexical ambiguity has developed not only theories on how comprehenders settle on a single meaning, but also experimental paradigms for examining this process.

INTRODUCTION

A small number of words in English are lexically ambiguous in that one spelling and/or one pronunciation is associated with two unrelated meanings – for example, 'spoke'. This small set of words has been the topic of hundreds of journal articles and book chapters since 1970. One reason for this great research interest is that almost all other words are 'polysemous' – they have multiple but related senses. Consider 'clear' as in 'passes light' versus 'easy to understand'; 'running' in 'running a marathon' versus 'running for election'; and 'paper' in 'wrapping paper' (substance) versus 'liberal paper' (institution). Britton (1978) reported that 44 percent of a random sample of English words had more than one dictionary definition. The more commonly a word is used, and the longer it has been part of the language, the more meanings it possesses (Zipf, 1945; Lee, 1990). Linguists and psycholinguists have wrestled with the proper treatment of the one-to-many mapping between word forms and word senses (Klein and Murphy, 2001), and many consider ambiguity to be the extreme end of a continuum of polysemy. Studies of ambiguity resolution thus concern a fundamental aspect of comprehension – how readers and listeners identify the contextually appropriate senses of words.

Most lexical ambiguity research has been conducted in English, but ambiguity and polysemy also occur in the world's other languages. For example, one-to-many mappings between pronunciations and meanings are prevalent in spoken Chinese (Li, 1998), so that by one count the syllable '*yi*' (with dipping tone) has 90 different meanings in Mandarin (Yip, 2001). (*See* **Lexicon**; **Lexical Semantics**; **Word Meaning, Psychology of**)

MODELS OF AMBIGUITY RESOLUTION

In everyday language use, the meaning of words is clarified by their context. Laboratory studies have focused on how comprehenders use context to arrive at the relevant word sense, and have suggested three different models. The exhaustive access model proposes that comprehenders first activate all possible senses of a word, then use context to select one meaning. The ordered access model suggests that comprehenders initially activate the most common sense of a word, and proceed to less common senses only when the initial meaning does not fit the context. The selective access model suggests that appropriate prior context can direct comprehenders to the relevant meaning of a word immediately. Hybrid models are also possible, for instance that access is selective when the context is strong, but that the most frequent meaning is initially accessed with less constraining context. The following text provides a snapshot of different and often conflicting empirical findings. For a discussion of computational models of lexical ambiguity resolution, the reader is directed to articles by Kawamoto (1993) and Dixon and Twilley (1999).

THE CONTEXT–AMBIGUITY–PROBE PARADIGM

A commonly used paradigm for investigating ambiguity resolution consists of three stimuli: a semantic context biasing one sense of the ambiguity, the ambiguous word, and a probe word. The context may be a single word ('iron bar' versus 'gay bar'), a sentence frame providing semantic context ('She covered the floor of the stable with clean straw') or a sentence frame providing syntactic context alone ('He needed to change' versus 'He needed some change'). Probe words are related to the contextually relevant sense of the ambiguity, to the irrelevant sense, or to neither (in the last example, 'clothes', 'coins' or 'water'). Responses to the probe word are the critical measure, in particular whether responses to irrelevant probes more closely resemble the relevant or the unrelated condition. Important factors include:

- the amount of time between the ambiguity and the probe
- the nature and strength of the context
- the dependent measure, or how the processing of the probe word is evaluated
- whether the sentence biases the more common (dominant) or less common (subordinate) meaning of the ambiguity (Simpson, 1994).

Two reaction time (RT) tasks are sensitive to semantic relationships: deciding whether a letter string is a word or a nonword (lexical decision time), and reading a written word aloud (naming latency). Table 1 shows a typical pattern of results in the context–ambiguity–probe (CAP) paradigm: when a short time elapses between the ambiguity and probe (around 200 ms), responses to the contextually irrelevant probes are faster than to unrelated words. When a slightly longer time elapses (around 700 ms), responses to the irrelevant probes are equivalent to those elicited by unrelated words (Swinney, 1979). These results have been taken as support for the exhaustive access model. The interpretation is that, when presented quickly enough, contextually irrelevant probes are processed as related because both meanings of the ambiguity are still active. A short time later, the second stage of semantic processing selects the contextually relevant sense of the ambiguity, and the contextually

Table 1. Typical reaction time (RT) results from the probe word paradigm. With a short period between onset of the ambiguous word and onset of the probe word, each of the three RTs was significantly different from the other two. This pattern of a three-way difference between conditions is often observed in the probe word paradigm, although the difference between contextually relevant and irrelevant conditions has not been statistically significant in all studies. With the longer period between the stimuli, the RT in the contextually relevant condition was faster than the other two conditions, which were not significantly different. Data from Van Petten and Kutas (1987)

	Mean naming latency time (ms)	
Probe type	*200 ms SOA*	*700 ms SOA*
Contextually relevant	591 (73)	547 (71)
Contextually irrelevant	617 (77)	562 (69)
Unrelated	635 (85)	571 (71)

Values are in ms, standard deviation in parentheses. SOA, stimulus onset asynchrony, the time between the onset of the ambiguous word and the onset of the probe word.

irrelevant probe is now processed as unrelated. (*See* **Language Comprehension, Methodologies for Studying**; **Lexical Access**; **Word Recognition**)

Nature and Strength of the Context in the CAP Paradigm

The finding of faster RTs for contextually irrelevant probe words than for unrelated probe words has been replicated many times and serves as the central support for the exhaustive access model. However, two other experimental findings are problematic for this model. The first is that the majority of experiments showing faster RTs in the contextually irrelevant condition compared with the unrelated condition also show that RTs in the contextually irrelevant condition are slower than those in the contextually relevant condition. A gradient of RTs across conditions is incompatible with all three of the major models in their purest forms. One possibility is that one of the major models is true, and that the pattern of contextually relevant < contextually irrelevant < unrelated RTs is due to imperfect stimulus construction. For instance, a proponent of the exhaustive access model might suggest that contextually relevant probes receive additional contextual support directly from the sentence context, as well as from the ambiguity itself, and that the former contribution is of no interest. A proponent of the selective access model might suggest that some portion of the contexts used in a given experiment were, in fact, too weak to count as good contexts for the desired meaning of the ambiguity.

The second experimental finding that precludes accepting the pure version of the exhaustive access model is that some studies have found equivalent RTs for contextually irrelevant and relevant words – results supportive of the selective access model (Tabossi and Zardon, 1993; Simpson, 1994). Many arguments in this research area revolve around defining both the nature and the strength of context which can (sometimes) lead to such results. For instance, Seidenberg *et al*. (1982) suggested a three-way distinction between (1) syntactic context ('a rose' and 'he rose'), (2) single-word associative context (as in 'ship–deck' and 'card–deck'), and (3) more global semantic context which is neither syntactic nor associative, but created by the overall meaning of a sentence. In this view, contexts of type 2 can indeed yield selective access because they work via direct word-to-word links within the mental lexicon, but contexts of types 1 and 3 are ineffective in blocking exhaustive access. A different view is that it is unnecessary to postulate different forms of context and that overall strength of context is the critical factor: strongly predictive contexts yield selective access, whereas weakly predictive contexts (such as 'a' or 'to') are much the same as no context at all (Paul *et al*., 1992).

The CAP Paradigm and Retroactive Context

Another important issue concerns the logic of the CAP paradigm itself. The standard interpretation of the paradigm is that reaction times to the probe reveal how the ambiguous word was initially interpreted, and that the probe itself has no additional impact. This interpretation assumes that the processing of sequential words is both serial and linear, so that each word can benefit only from what was presented earlier. However, several experiments with unambiguous words have shown that reaction times can be speeded, and error rates reduced, by the presentation of a related word shortly after the target word (Kiger and Glass, 1983; Dark, 1988; Van Petten and Kutas, 1991; Logan and Schulkind, 2000). These retroactive semantic context effects (sometimes called 'backward priming') are best understood in terms of temporal overlap in the processing of two words: if a second item is presented while the first is still being processed, both will benefit from their semantic relationship, much as a simultaneous pair of words are processed more rapidly if related than unrelated. A retroactive-context interpretation of the CAP paradigm suggests that access to a contextually irrelevant meaning is not a spontaneous response to reading an ambiguity, but is instead caused by presentation of the contextually irrelevant probe itself. Although retroactive context effects can clearly occur, the impact of this phenomenon in the CAP paradigm has been contentious (Burgess *et al*., 1989).

Event-related Brain Potential Measures in the CAP Paradigm

An undisputed finding of the CAP paradigm is that the results are sensitive to small differences in the timing of stimulus presentation, so that one appeal of the paradigm is the possibility of tracking the time course of language processing. A dependent measure that is particularly well suited to examining time course is the event-related potential (ERP), a measure of brain electrical activity that can be recorded as participants read or listen for comprehension. The ERP provides a continuous record of brain activity, so that one can describe the temporal onset and offset of experimental effects with some precision. One component of the ERP is sensitive to semantic context. The N400 (a negative voltage peaking 400 ms after stimulus onset) is elicited by all words, but is smaller in amplitude when a word fits with an established semantic context than when it does not (Van Petten and Kutas, 1994). (*See* **Event-related Potentials and Mental Chronometry**)

When a long period between the onset of one stimulus and the next (stimulus onset asynchrony, SOA) is used in the CAP paradigm, both contextually irrelevant and unrelated probe words elicit larger N400s than do contextually related probes (Figure 1a). These long SOA results are a perfect match with the typical pattern of reaction times. With a short SOA, the exhaustive access model predicts a large N400 only for unrelated probes, and equally small N400s for contextually relevant and irrelevant probes. The results in Figure 1b are somewhat different from this prediction. The semantic relationship between ambiguity and probe word influences the ERP beginning at 300 ms after the onset of the probe word. During the initial phase of the context effect, from 300 ms to 500 ms, the ERP to contextually irrelevant probes is similar to the response to completely unrelated words, indicating early access to only the contextually relevant meaning. Only some time later, from 500 ms to 1100 ms, does the contextually irrelevant response grow to resemble the contextually relevant response. This pattern of results is consistent with selective access, combined with a retroactive context effect. The contextually relevant sense of the ambiguity has a head start in influencing probe word processing, but temporal overlap in the processing of the contextually irrelevant sense and its related probe word is visible later.

EYE MOVEMENT MEASURES OF LEXICAL AMBIGUITY RESOLUTION

Gaze durations during reading have also been applied to the problem of ambiguity resolution. Readers generally spend longer fixating words that are contextually unpredictable or low in frequency of use. Gaze duration measures thus offer a naturalistic way of examining a reader's processing

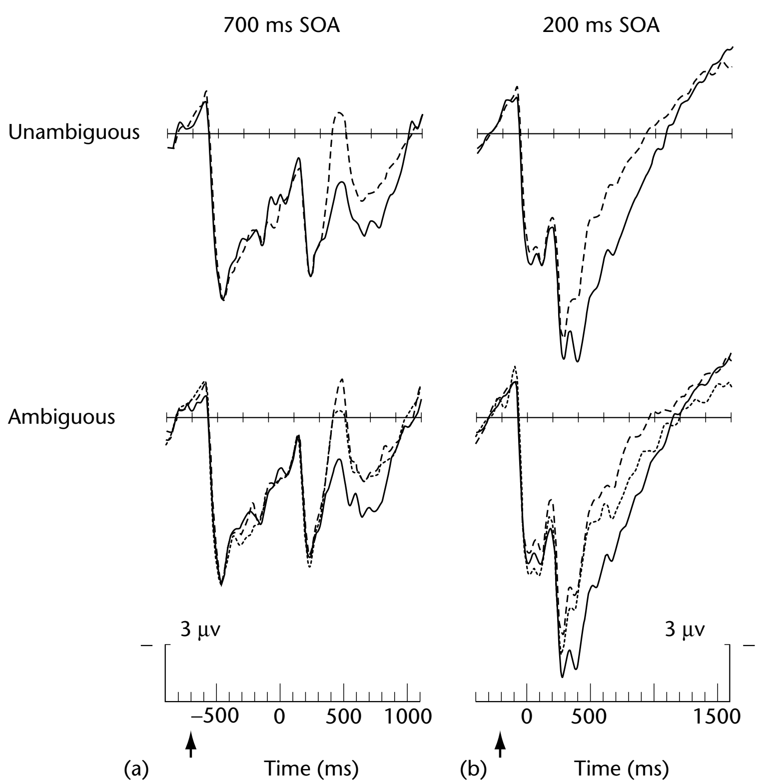

Figure 1. Grand average event-related brain potentials (ERPs) to ambiguous and unambiguous sentence terminal words and subsequent probe words which were unrelated (dashed line), contextually irrelevant (dotted line) or contextually relevant (solid line). Onset of the sentence terminal words is indicated by an arrow; onset of the probe words is at 0 ms. The ERPs were recorded at a midline central scalp site. Stimulus onset asynchrony (SOA) is 700 ms in (a), 200 ms in (b). Data from Van Petten and Kutas (1987); see also Van Petten (1995) for replication.

difficulty, without the need for an extra reaction time task. Because they do not include probe words, these measures thus avoid the possibility of retroactive semantic context effects.

In the absence of prior semantic context, gazes are longer on ambiguous words with two equally strong meanings (balanced homographs) than on unambiguous words, or on homographs with one dominant meaning. If subsequent portions of a sentence favor the subordinate meaning of an unbalanced homograph, readers spend a particularly long time on disambiguating regions. These findings suggest that readers favor the more common sense of an ambiguity on first reading, and must do some extra work if the two meanings are in close competition, or if their initial choice of meaning turns out to be incorrect.

When prior context biases one meaning, gaze durations for balanced homographs are like unambiguous words, indicating that readers no longer suffer a conflict between two equally likely interpretations (an apparent case of selective access). However, when the prior context biases the subordinate sense of an unbalanced homograph, gaze durations are longer on the homograph than on unambiguous words (Pacht and Rayner, 1993). The latter finding suggests that readers may access the dominant meaning despite the context, supporting the ordered access model. However, others have argued that this result depends on relatively weak contexts, and that strong contexts can produce selective access for even subordinate meanings (Kellas and Vu, 1999). Overall, the gaze duration research has lent little support to the exhaustive access model, but has instead indicated that meaning frequency and strength of semantic context are critical factors in determining which (and how many) meanings of ambiguous words are considered by readers.

CONCLUSION

Disagreements in the domain of lexical ambiguity resolution reflect our imperfect understanding of the sequence of events that yields the comprehension of any word. Future language research that sheds light on the nature of semantic relationships (thus allowing a better quantification of 'context'), and a detailed understanding of the time course of processing from sensory analysis to semantic integration are also likely to clarify how readers and listeners know when 'spoke' means 'part of a wheel' and when it means 'talked'. (*See* **Language Comprehension**; **Psycholinguistics**)

References

Britton BK (1978) Lexical ambiguity of words used in English text. *Behavior Research Methods and Instrumentation* **10**: 1–7.

Burgess C, Tanenhaus MK and Seidenberg MS (1989) Context and lexical access: implications of nonword interference for lexical ambiguity resolution. *Journal of Experimental Psychology: Learning, Memory, and Cognition* **15**: 620–632.

Dark VJ (1988) Semantic priming, prime reportability, and retroactive priming are interdependent. *Memory and Cognition* **16**: 299–308.

Dixon P and Twilley LC (1999) Context and homograph meaning resolution. *Canadian Journal of Experimental Psychology* **53**: 335–346.

Kawamoto AH (1993) Nonlinear dynamics in the resolution of lexical ambiguity: a parallel distributed processing account. *Journal of Memory and Language* **32**: 474–516.

Kellas K and Vu H (1999) Strength of context does modulate the subordinant bias effect: a reply to Binder and Rayner. *Psychonomic Bulletin and Review* **6**: 511–517.

Kiger JI and Glass AL (1983) The facilitation of lexical decisions by a prime occurring after the target. *Memory and Cognition* **11**: 356–365.

Klein DE and Murphy GL (2001) The representation of polysemous words. *Journal of Memory and Language* **45**: 259–282.

Lee CJ (1990) Some hypotheses concerning the evolution of polysemous words. *Journal of Psycholinguistic Research* **19**: 211–219.

Li P (1998) Crosslinguistic variation and sentence processing: the case of Chinese. In: Hillert D (ed.) *Sentence Processing: A Crosslinguistic Perspective*, pp. 33–51. San Diego, CA: Academic Press.

Logan GD and Schulkind MD (2000) Parallel memory retrieval in dual-task situations: I. Semantic memory. *Journal of Experimental Psychology: Human Perception and Performance* **26**: 1072–1090.

Pacht JM and Rayner K (1993) The processing of homphonic homographs during reading: evidence from eye movement studies. *Journal of Psycholinguistic Research* **22**: 251–271.

Paul ST, Kellas G, Martin M and Clark MB (1992) Influence of contextual features on the activation of ambiguous word meanings. *Journal of Experimental Psychology: Learning, Memory, and Cognition* **18**: 703–717.

Seidenberg MS, Tanenhaus MJ, Leiman JM and Bienkowski M (1982) Automatic access of the meanings of ambiguous words in context: some limitations of knowledge-based processing. *Cognitive Psychology* **14**: 538–559.

Simpson GB (1994) Context and the processing of ambiguous words. In: Gernsbacher MA (ed.) *Handbook of Psycholinguistics*, pp. 359–371. San Diego, CA: Academic Press.

Swinney DA (1979) Lexical access during sentence comprehension: (re)consideration of context effects.

Journal of Verbal Learning and Verbal Behavior **18**: 645–659.

Tabossi P and Zardon F (1993) Processing ambiguous words in context. *Journal of Memory and Language* **32**: 359–372.

Van Petten C (1995) Words and sentences: event-related brain potential measures. *Psychophysiology* **32**: 511–525.

Van Petten C and Kutas M (1987) Ambiguous words in context: an event-related potential analysis of the time course of meaning activation. *Journal of Memory and Language* **26**: 188–208.

Van Petten C and Kutas M (1991) Electrophysiological evidence for the flexibility of lexical processing. In: Simpson GB (ed.) *Understanding Word and Sentence*, pp. 129–174. Amsterdam: Elsevier.

Van Petten C and Kutas M (1994) Psycholinguistics electrified: event-related brain potential investigations. In: Gernsbacher MA (ed.) *Handbook of Psycholinguistics*, pp. 83–144. San Diego, CA: Academic Press.

Yip MCW (2001) A preliminary study of subjective frequency estimates of words spoken in Cantonese. *Psychological Reports* **88**: 1253–1258.

Zipf GK (1945) The meaning-frequency relationship of words. *Journal of General Psychology* **33**: 251–256.

Further Reading

Fabiani M, Gratton G and Coles MGH (2000) Event related potentials. In: Cacioppo JT, Tassinary LG and Berntson GG (eds) *Handbook of Psychophysiology*, 2nd edn, pp. 53–84. Cambridge, UK: Cambridge University Press.

Gaskell MGG and Marslen-Wilson WD (2001) Lexical ambiguity resolution and spoken word recognition: bridging the gap. *Journal of Memory and Language* **44**: 325–349.

Kutas M, Federmeier KD, Coulson S, King JW and Munte TF (2000) Language. In: Cacioppo JT, Tassinary LG and Berntson GG (eds) *Handbook of Psychophysiology*, 2nd edn, pp. 576–601. Cambridge, UK: Cambridge University Press.

Rayner K and Sereno SC (1994) Eye movements in reading: psycholinguistic studies. In: Gernsbacher MA (ed.) *Handbook of Psycholinguistics*, pp. 57–82. San Diego, CA: Academic Press.

Small SI, Cottrell GW and Tanenhaus MK (1988) *Lexical Ambiguity Resolution. Perspectives from Psycholinguistics, Neuropsychology, and Artificial Intelligence*. San Mateo, CA: Morgan Kaufmann.

Lexical Development

Advanced article

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CONTENTS

Lexical development refers to children's acquisition of meaningful and grammatical elements of the lexicon.

INTRODUCTION

What comes first? Many people think that words are children's first linguistic elements. This may be because words are the first meaningful units that we recognize in children's observable behavior. With the exception of scientists who study this topic, people rarely consider infants' production of well-formed but meaningless syllables like 'bababa' as evidence of language knowledge. However, words are not first in any scientifically interesting sense. Children develop multiple aspects of linguistic knowledge simultaneously, and they do so well before producing their first words. (*See* **Phonology and Phonetics, Acquisition of**)

One theme in this encyclopedia is information; another is information processing. The study of lexical development relates to both. First, lexical development refers to children's mastery of a kind of information. However, the evidence for such mastery is affected by information processing. This distinction between information and the processing of information is comparable to the distinction between competence and performance. Developmentalists face subjects who are clearly gaining both target competence (i.e. representation of information) and proficient performance (i.e. processing of that information). Limitations in