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LANGUAGE DEVELOPMENT

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readings of the meaning of that utterance initially and then inhibit a subset of these readings as they become irrelevant as more of the sentence is presented.

Potential evidence for such a role of working memory in language comprehension in children comes from studies of individuals with specific language impairment who have difficulties in sentence comprehension that appear to relate to working memory deficits rather than simply being a reflection of more general language problems. Similar evidence comes from research with children who have been classified as poor comprehenders. Although these children receive this classification on the basis of their difficulties in making sense of sentences that they read, in most cases, these difficulties extend to problems in listening comprehension and so are not reading specific. Rather, working memory difficulties are often seen among this population, and experimental studies have shown that poor comprehenders do find it difficult to update their mental models of an unfolding sentence and to inhibit irrelevant information.

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See Also: Auditory Processing and Language Impairments; Executive Functions and Language Development/Processing; Genetic Syndromes and Language Development; Less-Is-More Hypothesis; Parsing/Sentence Processing; Phonological Processes in Lexical Development; Processing Deficits in Children With Language Impairments; Reading Comprehension; Specific Language Impairment (Overview); Vocabulary Growth.

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Visual World Eye-Tracking Paradigm

Visual world eye-tracking paradigm (VWP) is an online experimental method to study spoken language processing that records participants' eye movements in the natural environment of comprehending and producing speech. It was first used to investigate the relationship between eye fixations and the meaning of simultaneously heard language by Roger Brown in 1974. This method did not catch on in adult psycholinguistics until 20 years later, when Michael Tanenhaus and colleagues published in *Science* the first VWP study of how English-speaking adults resolve temporary syntactic ambiguities of the type *Put the apple on the towel in the box* (where listeners may temporarily interpret *on the towel* as the apple's destination, as opposed to indicating which apple is to be selected, i.e., the one on the towel). The first application of the VWP to language acquisition research was the replication of this study of syntactic ambiguity resolution in 1999 by John Trueswell and colleagues in an investigation of the development of sentence-processing mechanisms in 5- and 9-year-old children.

The eye-tracking equipment used in psycholinguistic VWP studies is relatively inexpensive, can be portable, and allows for automatic and highly accurate measurement of eye movements. There are two major classes of eye-tracking equipment that are used to record children's eye movements. The first one is an advanced adaption of the Preferential Looking Paradigm known as Looking-While-Listening. It was pioneered by Anne Fernald and colleagues and is primarily used with infants and toddlers (14–36 months) as it records the direction of the child's face and eyes relative to the environment as the gaze shifts between two separate screens in response to spoken instructions. Its variation, the so-called Poor Man's Eye-Tracker, is typically used with toddlers and children (36 months and on), where the number of options to look at is expanded from two screens to

four corners of a vertical display. Equipment required for both the Looking-While-Listening and the Poor Man's Eye-Tracker includes a digital camcorder and video-editing software for frame-by-frame analysis of recorded eye movements, with superimposed spoken instructions. The second class comprises the more sophisticated pupil–corneal reflection eye-trackers that continuously measure the position of the eye relative to the head and record actual saccades and fixations. Eye-trackers can be head mounted or free-viewing remote depending on whether the participant views and interacts with real objects in the world or pictures and video clips presented on a screen, respectively. The four brands of eye-trackers that are the preferred choices for the VWP studies with children are Tobii (Tobii Technology), EyeLink (SR Research), SMI (SensoMotoric Instruments), and ISCAN (ISCAN, Inc).

The successful application of the VWP to study spoken language is based on the mind–eye hypothesis, namely, that speakers and listeners tend to look at what they attend to in the visual world. Eye movements reflect attention shifting between referents; they are rapid, incremental, and often anticipatory. There is evidence that eye movements are language mediated from early on in child development, making the VWP the best option among online methods in developmental psycholinguistics. It measures visual attention when it is paired with speech, allowing researchers to conduct experiments with children under typical conditions of looking and listening or acting upon spoken instructions. This technique is user-friendly as it does not require meta-cognitive tasks or literacy, it does not tax working memory, and it is safe. It is applicable to a wide range of ages (from 14 months and on) and populations (e.g., children with specific language impairment, cochlear implants, or autism spectrum disorders; bilingual children).

The VWP eye-tracking studies with children investigate a wide range of language domains from spoken word recognition to interface-based phenomena. In some domains, children's patterns of eye movements are very similar to those of adults, although their speed and efficiency in language processing continue to improve from infancy through childhood. In spoken word recognition, infants and children demonstrate sensitivity to lexical competition in cases when words start with the same onset (the cohort effect); from a young age, toddlers can take advantage of gender-marked information on articles and adjectives to access words faster. They can also use contrastive prosody, construct filler-gap dependencies between wh– words and their initial positions in questions, and establish anaphoric relations between pronouns and their referents to resolve referential ambiguities online. In other domains, such as the processing of verb-argument structure, resolving temporary syntactic ambiguities, and universal quantification, children as old as 6 years differ from adults, and the VWP is essential in providing an insight into the cause of children's sentence comprehension errors. When they make errors, their patterns of eye movements in incorrectly interpreted sentences reveal that children over-rely on lexical properties of the verbs, pay excessive attention to visually salient but irrelevant referents, and often process spoken language deterministically, being unable to revise their initial incorrect interpretations.

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See Also: Parsing/Sentence Processing; Preferential Looking Paradigm/Head-Turn Preference; Spoken Word Recognition.

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