The development of phonological representations for perception and production

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Research questions and goals

This programme investigates the acquisition of phonological representations in the lexicon and the role of these representations in perception and production. Acquiring a first lexicon is a nontrivial task. Children must discover how the acoustic stream can be parsed into units with a systematic form-meaning relationship. These smaller units form the entries in the mental lexicon and contain phonological, morphological, and semantic information. The core issue in this proposal is when and how children use phonological knowledge for perception and production. Our main claim is that phonology has a dual role with respect to lexical representations: it (a) provides cues to potential boundaries of meaningful units and (b) enables learners to create abstract lexical representations. The programme comprises a detailed study of the development of the Dutch voicing contrast in perception and production, and its encoding in lexical representations.

Voicing in Dutch has several interesting properties making it an ideal test case for theories of phonology and its development (Trommelen & Zonneveld 1979, Mascaro & Wetzels 2001). Contrasts in word-initial position convey semantic differences, but word-finally, contrasts are neutralised. However, contrasts reappear if vowel-initial suffixes are added, as in plurals (*hon*[t] *hon*[d]-*en* 'dogs'). Moreover, Dutch has regressive and progressive voice assimilation in different (morpho-)phonological contexts, producing substantial surface variation in stem and affix shapes. Also, the acoustic correlates of voice differ depending on position in the word (Slis 1985). For all these reasons, acquisition of the phonology of voicing poses children a genuine challenge.

Embedding in current research

Infants know a great deal about the phonology of a language before they know any words. Most of what infants learn about language bears on sounds, not meaning. Children recognise stress, phonotactics, and segmental inventories of their mother tongue from a very early age (Jusczyk 1997), long before they start producing words, and 7.5–month-olds use this phonological knowledge for word segmentation (Jusczyk, Houston & Newsome 1999). However, we do not know the connection between information extracted by young infants, and the meaningful words acquired and used later in development.

Most studies of children's production assume that words are perceived in full detail and stored as phonetic or phonemic representations (Smith 1973, Bernhardt & Stemberger 1998). The child's phonology is held responsible for the change from these representations to the child's simplified output form. This view raises several questions. If children perceive phonotactic details, why do they simplify their outputs rather than using the same phonological knowledge for production and perception? It is widely accepted that explanations of children's production simplifications in terms of articulatory immaturity do not account for all the available data. To solve this puzzle, we need to study how phonological contrasts develop, and how phonological representations are constructed and used for both perception and production.

Little research has addressed children's learning of adult phonological alternations, in spite of their central status in theoretical phonology (Macken 1995). Moreover, little is known about the acquisition of productive inflection in Dutch. The central issue is how children store lexical items and represent relationships between contextual variants. For example, the word *hond* ‘dog’ is pronounced [hɔnt], and the word *lont* ‘fuse’ is [lɔnt]: these words rhyme. Their plurals, however, formed with the suffix *-en*, do not rhyme: ‘dogs’ is [hɔndən], ‘fuses’ [lɔntən]. The voicing contrast, apparent in the plural, is neutralised in the singular due to a phonological rule devoicing word-final obstruents. How do children learn alternations? How is this learning guided by phonotactic knowledge? How abstract are lexical entries of alternating items? These are nontrivial questions, all revolving around the nature of early phonological representations.

Descriptions of subprojects

PROJECT I. Early acquisition of phonotactics – Tania Zamuner (KUN)

This project addresses the early acquisition of the phonotactics of Dutch voicing. We will identify phonotactic regularities concerning Dutch voicing which are available to infants, and ascertain how much of this information infants actually acquire and use for word segmentation. To that end, we (a) examine the statistics of voicing regularities in the child’s input, (b) carry out perceptual experiments with infants, and (c) conduct complementary computational analyses of the input.

The statistical analysis of the input will be conducted using a corpus previously collected for exactly this sort of research (Van de Weijer 1998). It contains >85.000 transcribed utterances of Dutch speech directed to an infant of 6-9 months. Preliminary analyses of a smaller corpus suggest that considerable contextual information regarding the distribution of voiced and unvoiced consonants is available in the input even if no apriori knowledge of word boundaries is assumed. We will analyse the distribution of voicing in various contexts, distinguishing between hard (absolute) and soft (probabilistic) regularities; this will provide background for the perception work.

To test whether infants are sensitive to voicing regularities, we will use a standard task termed the Head-Turn Preference Procedure (HPP; Kemler Nelson et al. 1995) with infants between 7 and 12 months. HPP studies in many labs have revealed infants’ knowledge that certain phonetic sequences are anomalous (Friederici & Wessels 1993; Jusczyk et al. 1994). If Dutch infants are sensitive to voicing regularities, we predict this sensitivity to be reflected in perceptual preferences. For example, infants may prefer lists of syllables ending in unvoiced stops over syllables ending in voiced stops; however, they may not show this preference for lists of words beginning with unvoiced stops, since Dutch has an initial voicing contrast. This pattern of results would suggest that infants possess an early foundation for the final devoicing rule even before they have demonstrated lexical knowledge. We will also carry out experiments to evaluate whether infants generalise the preference for utterance-final unvoiced obstruents across the set of unvoiced obstruents, or only over those which are frequent in the input (as estimated from the Van de Weijer corpus).

The final set of experiments in this project aims to ascertain to what extent infants use voicing phonotactics for word segmentation, facilitating lexical acquisition. Our starting point is the notion that voiced obstruents in final-devoicing languages serve as a *continuity cue*. Thus, given a sequence (C)VCV(C), the lexical segmentation (C)VC#V(C) is impossible if the medial C is a voiced obstruent. Infants disfavouring segmentations with voiced obstruents as codas should prefer to segment such sequences as (C)V#CV(C). Infants’ use of phonotactic regularities for segmentation will be assessed in experiments using the familiarisation-preference version of HPP pioneered by Jusczyk and Aslin (1995), who showed that infants can detect occurrences of previously familiarised words in continuous speech.

Finally, we will use the Van de Weijer corpus to evaluate computational models of the segmentation process, in which knowledge of probabilistic phonotactics constrains hypotheses about words in the input. This will permit testing of the potential benefits of such knowledge for the early stages of word discovery.

Planning

Year 1: Literature review, training in research methodology. Statistical analysis of input data (Van der Weijer corpus). Developing and pretesting stimuli for preference and word segmentation experiments. Selection of subjects. First experiment.

Year 2: Phonotactic preference experiments. Data analysis.

Year 3: Segmentation experiments. Data analysis. Computational analyses of speech input. Correlating results with those from Project II and with computational analyses.

The work will be performed in the new infant perception laboratory being set up on the Spinoza project. Prof. Cutler has made the facilities of this lab available to the project. Together with dr. Swingley, she will serve as consultant for the experimental work.

PROJECT II. Building a phonological lexicon – Suzanne van der Feest (KUN)

This project investigates the distribution of voicing in production data, and compare phonological knowledge of voicing in Dutch used in production and perception by children aged between 1 and 3.

A common view is that development proceeds from phonemes to words, and then phonological rules are abstracted. We propose an alternative view in which phonological regularities detected in infancy guide the learning of words (i.e. lexical representations) and form the basis of the child’s morphophonology. We will analyse the presence or absence of voicing in the whole production vocabulary of each child at each developmental stage, to ascertain when, where and how voice is represented in the lexicon. We will use the CLPF-database (Levelt 1994, Fikkert 1994), which contains naturalistic longitudinal data of 12 children acquiring Dutch.

Very little is known about perception of speech as meaningful language in this age group. One-year-olds may not use all of their early knowledge of sound form when learning words (Stager & Werker 1997). This project will conduct perceptual experiments to evaluate in more detail the link between children’s representations for speaking and for recognising words. Underspecification theory predicts asymmetry between mispronunciation of voiced vs. unvoiced obstruents depending on position in the word (cf. Project I and III). Recent results using a visual fixation procedure (Golinkoff et al. 1987) suggest that children encode the onsets of words in detail (Swingley & Aslin 2000): e.g., 18-month-olds represent /d/ in *dog* with sufficient detail that the mispronunciation *tog* is difficult to recognise. However, the reverse case (*toy* as *doy*) has not been studied. Also, both the phonetics and the phonology of voice distinctions differ substantially in English and Dutch. We will use this procedure to evaluate children’s representation of word-initial, word-final and word-medial consonants. Thus, children will be tested for recognition of *hond* using [+voiced] and [-voiced] pronunciations of the crucial t/d consonant. We will elicit production data from the children participating in the perception experiments, enabling us to investigate via acoustic analyses whether children use phonetic cues to indicate the voicing contrast, or whether their production is variable. If, for example, the voicing of word-final consonants is underspecified, children may resolve this in their speech by producing intermediate or more variable realisations of the voicing of those consonants.

Planning

Year 1: Literature review, training in research methodology. Phonological analysis of available production data. Developing and pretesting stimuli for perception experiments.

Year 2: Perception experiments: word-onset and word-medial position. Elicitation of production data. Data analysis.
Year 3: Perception experiments: word-final position. Elicitation of production data. Data analysis. Correlating results with those from Project I. Begin acoustic analysis of production data.
Year 4. Finish acoustic analysis of production data. Writing dissertation.

Dr. Swingley (MPI for Psycholinguistics, Nijmegen) will serve as consultant for the experiments.

PROJECT III. The phonology-morphology interface – Annemarie Kerkhoff (UU)

This project examines how Dutch children (ages 2;6 until early school age) learn phonological alternations, i.e. store lexical items and represent the relationship between their contextual variants, guided by their previously acquired knowledge of hard and soft phonotactics. The project will be the first specific study of the development of alternations, tracking this development in children's production *and* perception.

The logical problem of learning alternations is nontrivial. To solve it, children must construct representations which are more abstract than the forms they hear. When children recognise that *hon*[t] and *hon*[d]*en* are related (presumably by noting their semantic overlap), they can use phonotactic knowledge gained in infancy to infer the lexical representation, and then use this too to derive singulars of newly-heard plurals.

The reverse problem, of deriving plurals from singulars, is insoluble in principle: if only the singular's surface form is known, the plural may contain either a voiced or unvoiced consonant. One possibility is that children match the singular's voicing value, producing alternations like *hon*[t] ~ **hon*[t]*en*; another is that children resort to knowledge of the likelihood of voicing in various contexts (soft phonotactics, Cutler & Carter 1987, Brent & Cartwright 1996), resulting in overgeneralizations of voicing (e.g., **bul*[d]*en* 'lumps', Kager 1999).

In sum, children must learn how to compute a stem's surface form from its abstract lexical representation by the phonology, as well as to project novel plurals from underspecified singulars. This learning process will be studied via methods involving both production and perception: database research, experimental elicitation of plurals, recognition tests.

We will draw on the CLPF database mentioned above, and also the Groningen and Wijnen corpora. These data will be analysed with respect to the phonotactic regularities studied in Projects I and II. Specifically, we will evaluate to what extent children's productions of voiced and voiceless obstruents in plurals align with phonotactic probabilities. Realisations of plurals will be studied in tandem with the developing voicing contrast. Special attention will be paid to overgeneralizations of voicing in children having stable voicing contrasts in production (e.g., **hon*[t]*en* or **bul*[d]*en*).

We will further conduct experiments using elicited plurals. This task (the *wug*-test; Berko 1958) reveals children's generalisation strategies, and their internalised knowledge of voicing alternation. We will teach children nonsense singulars, such as [*ke:t*], and then elicit plurals, which may emerge as *keten* or *keden*. Developing mastery of the alternation should be reflected in performance improvement with age.

In perception experiments (using picture recognition), we will teach children novel forms, and then ask them to identify these in related forms alternating in different ways. The first experiment will test identification of a training item (a singular such as [*ke:t*]) in different plural test items ([*ke:den*] and [*ke:pen*]). A second experiment will test the identification of pre-trained plural stems (e.g. [*ke:den*]) presented in singulars, again controlling for alternation type ([*ke:t*] versus [*ke:p*]). The final experiment will train on nonsense paradigms and test for identification of the entire paradigm. Training paradigms alternate in voicing {[*ke:t*] ~ [*ke:den*]}, or place {[*ke:t*] ~ [*ke:pen*]}. We will test identification of singulars and plurals separately. The test will be repeated after a week to verify whether children have internalised the paradigm.

Planning

Year 1: Literature review, training in research methodology. Analysis of available data on allomorphic variation in existing databases. Developing and pretesting stimuli for elicitation and recognition experiments.

Year 2: Elicitation and recognition experiments with children from 2.6-3.6. Data analysis. Comparison with statistical analysis of input from project I.

Year 3: Elicitation and recognition experiments with children from 3.6-5. Data analysis. Comparison with results of project II. Relating perception and production experiments.

Year 4. Writing dissertation.