The lexical utility of phoneme-category plasticity

Anne Cutler
MPI for Psycholinguistics
James McQueen
MPI for Psycholinguistics
Dennis Norris
MRC Cognition and Brain Sciences Unit

The lexical utility of phoneme-category plasticity

Abstract.
Exposure to an accented production of a particular phoneme in word contexts induces a shift in listeners' representations of the inclusiveness of that phoneme category. In a lexical decision experiment, the same ambiguous phoneme (between /f/ and /s/) replaced /f/ in 20 words ending with /f/ (e.g. carafe) for some listeners, while for others it replaced /s/ in 20 words ending with /s/. A subsequent phonetic categorisation experiment showed that the /f/ category had become more inclusive for the former group, while the /s/ category became more inclusive for the latter group (Norris, McQueen & Cutler, 2003). Importantly, exposure to the same ambiguous sound in a nonword context had no effect on category boundaries. The observed plasticity could not be accounted for by adaptation or contrast effects; Norris et al. argued that the plasticity occurred in the service of word recognition. Adjusting category boundaries allowed more rapid recognition of an unusual speaker's speech.

The lexical utility of phoneme-category plasticity

Adjustment would be useless if it did not generalise to other words. In further research the same exposure conditions were used, but the phoneme categorisation test phase was replaced by a test phase involving another lexical task, capitalising on cross-modal identity priming effects: recognition of a written word is faster if the same word has just been heard. The critical words in this case were /f/-/s/ minimal pairs (e.g. knife-nice). The spoken form ended with the ambiguous sound, and at issue was how much priming this form produced for recognition of the two written words. For listeners with initial-phase exposure to the ambiguous sound replacing /f/, more priming resulted for words ending with /f/ (knife), while for listeners with /s/-exposure more priming resulted for /s/-words. Thus the learning generalised from the 20 words used in the first phase to the rest of the lexicon, as predicted. This suggests that the utility of phoneme-category plasticity is indeed facilitation of word recognition.

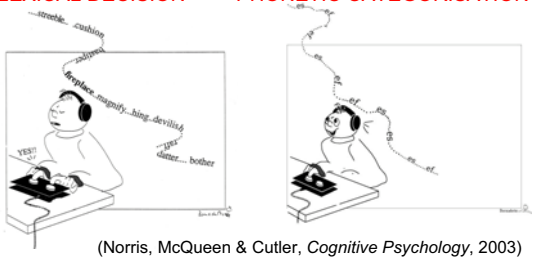
Why does language change spread across the community?

- The pronunciation of phonemes in any language changes over time
- Change affects the entire community, not just younger speakers (cf. Harrington et al.'s study of the Queen's English – even that changes)
- The change obviously requires perceptual adaptation – speakers adapt to what they hear
- But why do speakers adapt? What do they get out of changing the way they speak?

Perceptual learning in speech

A 2-part procedure for inducing language change in the speech perception laboratory:

LEXICAL DECISION PHONETIC CATEGORISATION



(Norris, McQueen & Cutler, *Cognitive Psychology*, 2003)

Perceptual learning in speech

In Part 1 (lexical decision), listeners are exposed to an altered sound

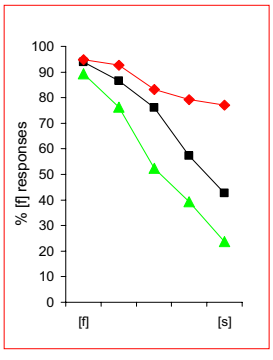
Some listeners hear this sound instead of [f], some hear it instead of [s]

Part 2 (phonetic categorisation) tests the effect of this exposure on [f]-[s] decisions

Perceptual learning in speech

- Part 1: Lexical decision
  - Group I. 20 ambiguous [f]-words (e.g. *olij?* from *olijf*) + 20 natural [s]-words (e.g. *radijs*)
  - Group II. 20 ambiguous [s]-words (e.g. *radij?*) + 20 natural [f]-words (e.g. *olijf*)
  - Group III. 20 non-words with [?] (e.g. *gloe?*)
  - OR: Group IIIa. 20 non-words with [?] (e.g. *gloe?*) + 20 natural [s]-words (e.g. *radijs*); Group IIIb. 20 non-words with [?] (e.g. *gloe?*) + 20 natural [f]-words (e.g. *olijf*)
- Part 2: Phoneme categorisation ([f]-[s]); all groups had the same test

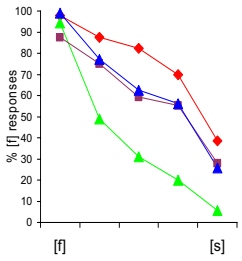
Perceptual learning in speech



- I. *Olij? + radijs*
- II. *Radij? + olijf*
- III. *Gloe?*

Exposure to a changed sound in the context of real words resulted in perceptual adaptation

Perceptual learning in speech



- I. *Olij? + radijs*
- II. *Radij? + olijf*
- III. *Gloe? + radijs*
- IV. *Gloe? + olijf*

Again, only real-word contexts induced perceptual adaptation

Generalisation of perceptual learning in speech

- The perceptual learning which Norris et al. induced in the laboratory only appeared when listeners heard the altered sound in words, allowing interpretation of the sound as [f] or [s]
- The learning led to a category boundary shift
- Subsequent experiments showed that the adjustment can be speaker-specific, allowing rapid adaptation to speaker-specificity (Eisner & McQueen, in press), and it persists (Eisner, forthcoming; Kraljic & Samuel, 2004). These characteristics are presumably very useful!

Generalisation of perceptual learning in speech

- But to be really useful to the listener, the adaptation should of course generalise to other words (not heard in Part 1). The learning should facilitate future word recognition.
- Note that the shift in the category boundary already indicates generalisation.
- However, we can also test generalisation directly in a word recognition task

Generalisation across words?

- To test generalisation of adaptation to other words, we need to see if a new word containing the ambiguous sound is heard as containing (depending on Part 1) unambiguous f or s
- Ideally, this means using minimal pairs (such as *knife-nice* in English)
- Our test: Is *doo*? heard as *doof* or *doos*? (Dutch *doof* = deaf, *doos* = box) - and many more such minimal pairs.

(McQueen, Cutler & Norris, submitted)

Generalisation across words?

- Part 1: lexical decision, as before:
  - Group I: [?] is [f] (*olij?* + *radijs*)
  - Group II: [?] is [s] (*olijf* + *radij?*)
- Part 2: testing the minimal pairs
  - Testing via simple lexical decision is impossible!
  - We really want to find out what word listeners have heard, without explicitly asking them…
  - So: priming experiment with *doof*/*doos.*

Generalisation across words?

- Part 1: lexical decision
- Part 2: priming experiment with *doof*/*doos*

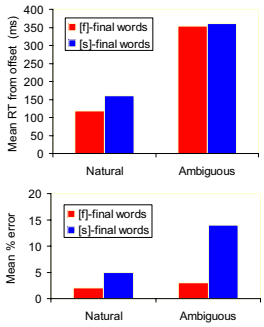
Priming (= faster responses) if prime and target are the same

Spoken prime	Visual target
doo?	DOOF
doo?	DOOS
krop	DOOF
krop	DOOS

Generalisation across words?

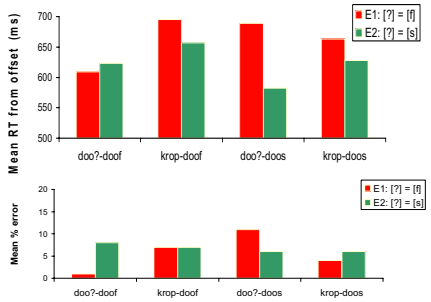
- Part 1: lexical decision:
  - Group I: [?] is [f] (*olij?* + *radijs*)
  - Group II: [?] is [s] (*olijf* + *radij?*)
- Part 2: priming experiment with *doof*/*doos.*
  Predictions:
  - Group I: hears *doo?* as *doof;* → more priming for DOOF
  - Group II: hears *doo?* as *doos;* → more priming for DOOS

Lexical decision (Part 1) results

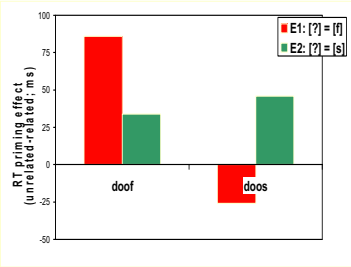


- Listeners responded more rapidly to items ending in natural fricatives, as in the original experiments
- Most [?]-final items were identified as Dutch words. There was a small bias towards [f] responses.

Cross-modal identity priming (Part 2) results



Amount of priming across groups



Group 1 listeners, who had heard [?] as [f], showed more priming for f-final words (DOOF) than for s-final words (DOOS).

Group 2 listeners, who had heard [?] as [s], showed more priming for s-final words (DOOS) than for f-final words (DOOF).

Thus the perceptual learning generalised across words.

Generalisation across words?

- Yes, the perceptual learning effect generalises to new words, not heard in training.
- The locus of the perceptual learning thus must be at the prelexical level – learning at the lexical level, or at a postlexical phonemic decision level, would not generalise across words.
- Note that these results challenge models which have no prelexical level representing speech sounds and no abstract lexical representations - such as radical episodic/exemplar models.

Why does language change spread across the community?

- Speakers adapt to what they hear
- The resulting perceptual adaptation pays off in the form of better word recognition
- Production models follow perception models, so change spreads across the community; but the root cause is facilitation of word recognition