PERCEPTUAL WEIGHTING AND PHONEMIC AWARENESS IN PRE–READING AND EARLY–READING CHILDREN

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ABSTRACT

While metalinguistic awareness and speech perception have been found to each be related to numerous other linguistic processes, e.g. reading acquisition, phonological development, phonological disorders, it is only recently that the relationship between awareness and perception has been considered. Recent studies have demonstrated correlations between changes in perceptual weighting of acoustic cues and the development of metalinguistic skills at the phonemic level. This finding raises questions as to the exact nature of the correlation between the two processes. Is the relationship strictly linear, or could one of the two processes have a causal influence on the development of the other? This paper discusses the results of a longitudinal study of beginning–reading children, and a cross–sectional study of older pre–reading children, both of which aim to address the issue of causality in the relationship between perceptual weighting and phonemic awareness.

1. INTRODUCTION

1.1. Perceptual weighting

Numerous studies have shown that while every speech contrast is signalled by multiple acoustic cues, listeners do not use all acoustic cues to the same extent in their identification of these contrasts [2]. Several studies of children's perception, in particular, suggest that dynamic transitional cues are more important to children than to adults in labeling certain contrasts [6, 4, 7, 1]. Nittrouer and colleagues [6, 4], for example, found that when they presented adults and children (3– to 7–years–old) with stimuli in which steady–state and transitional cues were in conflict, the children showed greater effects of the transitions than did the adults.

The stimuli used in Nittrouer's studies were created first by excising the vowels (both the formant transitions and the steady–state formants) from two fricative–vowel words: e.g. /su/ ("Sue") and /ʃu/ ("shoe"). Two continua of fricative noises were then created, ranging from a clear /s/ to a clear /ʃ/. The two vowels were then concatenated onto the fricative noises, the vowel from one word onto one continuum, and the vowel from the other word onto the other continuum. The resulting stimuli were therefore two continua ranging from /su/ to /ʃu/, one with formant transitions appropriate for "Sue" and one with formant transitions appropriate for "shoe" (see Figure 1 for a stylised diagram of this type of stimuli).

When asked to label these stimuli, both adults and children gave more "sh" responses to stimuli which had transitions appropriate for /ʃ/. As noted above, however, children were more affected by the transitions: they gave substantially more "sh" responses than did adults to the /ʃ/–transition stimuli.

A further study [4] showed that children do not simply prefer transitional information across the board. While formant transitions which occur *within* a CV syllable seem to be of perceptual importance to children, Nittrouer found that children seem to be *less* sensitive than adults to transitions which occur *between* syllables.

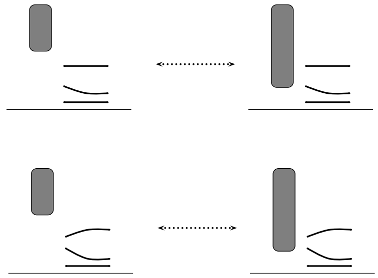

Figure 1: Stylised "spectrograms" of endpoints of two /so/–/ʃo/ contunua. The top continuum has formant transitions appropriate for /(s)o/ (*sew*); the bottom continuum has transitions appropriate for /(ʃ) o/ (*show*).

Nittrouer suggests that these developmental changes in the weight given to transitional cues (which she refers to as a Developmental Weighting Shift) result from a change in the size of perceptual units: children tend to perceive speech in terms of syllabic units, giving more weight to the acoustic cues which "ensure [their] perceptual coherence" [6, pp.328] (i.e. syllable–internal transitions). This sensitivity decreases with age, however, and adults tend to perceive speech in terms of phonemic segments [6, 4, 5]. Nittrouer [5] goes on to suggest that these changes in perceptual strategy might be related to the conscious discovery of sub–syllabic structure: that is, the development of phonemic awareness.

1.2. Phonemic awareness

The development phonemic awareness is part of a process generally known as metalinguistic awareness, in which individuals become able to consciously think about and manipulate units of speech of varying sizes. The development of these skills seems to move in a manner similar to that suggested by Nittrouer [6, 4] for the development of perceptual weighting: i.e. from syllable–sized units to phoneme–sized units. When children first become aware of language, they are at first only able to think about the larger units of speech, i.e. words, morphemes and syllables (and possibly onset/rime units). At this stage of metalinguistic development, children can rhyme and can identify the "beginning sound" of a word like *please* as /pl/. As children begin to learn to read, however, it becomes necessary for them to be able to explicitly identify the smaller units of speech (i.e. phonemes) in order to be able to make the connections between orthographic representations and the sounds that they represent. Individuals who have developed phonemic awareness will be able to identify the "beginning sound" of *please* as /p/, and to segment the word into its component phonemes: /p/–/l/–/i/–/z/ [3].

1.3. Relationship between perception and awareness

Nittrouer [5] conducted a study to investigate the extent to which developmental changes in weighting of acoustic cues could be related to the development of phonemic awareness. The results of the study showed a significant correlation between the two processes: high levels of phonemic awareness were related to "adult–like" perceptual weighting, and low levels of phonemic awareness were related to "child–like" perceptual weighting. However, because this was a cross–sectional study, the results did not give any indication of causality or directionality in the relationship. It is possible, therefore, that the two processes could develop in tandem with each other, or alternatively (as noted by Nittrouer [5]), the development of one of these processes could be a requirement for the development of the other.

The main goal of the current study, therefore, is to address this issue of causality. Experiment 1, a longitudinal study, was designed to establish i) if perceptual weighting and phonemic awareness develop in tandem, or if one process develops before the other, and ii) (if the latter is the case) if ability in one process at an early stage of the study is predictive of ability on the other process at a later stage of the study. Experiment 2 was designed to determine whether one of the processes (perceptual weighting) could develop in the absence of development in the other process (phonemic awareness).

2. EXPERIMENT 1

2.1. Subjects

10 adults and 20 children, all native speakers of English, participated in this experiment (2 children did not complete the study). None of the subjects suffered from or had ever been treated for hearing or speech disorders, and all adult subjects were normal readers. The average age of the children at Stage 1 of the study was 5 years, 8 months. At the beginning of the study all of the children were in their first year of full–time primary education (all had commenced their second year by the end of the study).

2.2. Method

The children were tested on their perceptual weighting and phonemic awareness 3 times, at 2.5 month intervals. The adults were tested once, on their perceptual weighting only.

2.2.1. Perceptual weighting The stimuli for the perceptual tests were based on those used by Nittrouer [6, 4, 5], as described above. Specifically, the stimuli were designed so that two cues to the place of articulation of the fricatives /s/ and /ʃ/ (static fricative noise and dynamic formant transitions) were in conflict. In this way it could be determined which cue was more heavily weighted by subjects in their labeling of the fricatives. The two continua ranged from /ʃo/ (*show*) to /so/ (*sew*). The adults labeled the stimuli by ticking boxes on a form provided; the children were given counters to place on pictures which corresponded to the two words.

2.2.2. Phonemic awareness Two tests of phonemic awareness were administered: *phoneme blending* and *phoneme segmentation*. For the phoneme blending test, the children were presented (aurally only) with words that had been broken up into "small bits" (i.e. phonemes) and were asked to blend the sounds back together

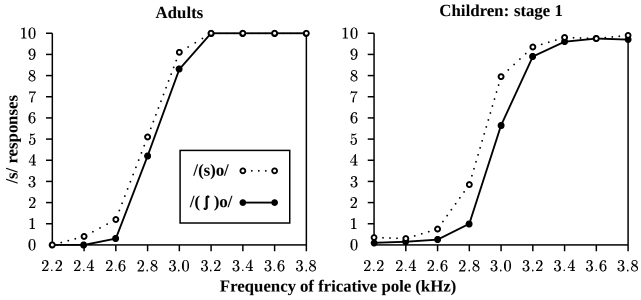

Figure 2: Perceptual weighting responses for adults, and children at Stage 1, presented in number of /s/ responses per stimulus. Two response curves are presented for each group, corresponding to the two continua of stimuli.

to form a word, e.g. "f–r–o–g" becomes "frog". For the phoneme segmentation test, the children were presented (again, aurally only) with whole words and asked to segment them into "small bits", e.g. "frog" becomes "f–r–o–g".

2.3. Analysis

2.3.1. Perceptual weighting The raw perceptual weighting scores (in terms of number of /s/ responses: see Figure 2) were analysed using a probit transform. This transform gives values which approximate the slope of the response curve (the degree of categorical–ness of the responses) and the point along the fricative noise continuum at which responses change from predominantly /ʃ/ to predominantly /s/ (the category boundary). Because two continua were used, each with different formant transitions, a third value could be calculated, namely the difference between the two category boundaries (a measure of the degree to which the listener was affected by the transitional cues). Perceptual weighting will be referred to as either adult–like (little separation between category boundaries, and therefore less affected by transitional cues) or non–adult–like (greater separation between category boundaries, and therefore more affected by transitional cues).

2.3.2. Phonemic awareness The phonemic awareness tests were scored out of a possible 50 for each test. In order to avoid confounding any difference in cognitive demands between the tests with the level of phonemic awareness tapped by the two tests, the results for phoneme blending and phoneme segmentation were not combined.

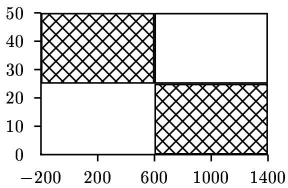

Figure 3: Stylised representation of a linear pattern of correlation between perception and awareness. Perception, on the x–axis, is divided into adult–like (left) and non–adult-like (right). Awareness, on the y–axis, is divided into good (top) and poor (bottom).

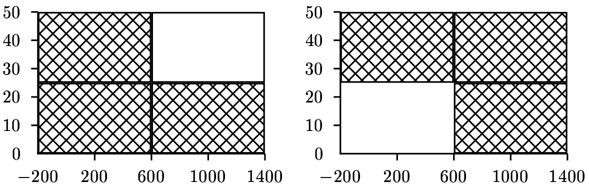

Figure 4: Stylised representation of a non–linear pattern of correlation between perception and awareness. See caption of Figure 3 for further description.

2.3.3. Relationship between perceptual weighting and phonemic awareness Figures 3 and 4 illustrate possible distributions of data that could be expected to be seen if a relationship (linear or otherwise) does in fact exist between perceptual weighting and phonemic awareness. The graphs show perceptual weighting in terms of separation of category boundaries (x–axis), and phonemic awareness in terms of score out of 50 (y–axis). The graphs are divided into quadrants at estimates of the adults' most "child–like" perception, and the median phonemic awareness scores.

If the relationship is strictly linear, then the data should fall into a bi–modal distribution such as that illustrated in Figure 3. In this graph, subjects with adult–like perception always have high phonemic awareness scores, while those with non–adult–like perception have low phonemic awareness scores.

If, on the other hand, one of the two processes develops before (and possibly has a causal influence on) the other, then the data should fall into a distribution more like that illustrated in the graphs in Figure 4. In these two graphs, subjects with "high" scores in both processes and subjects with "low" scores in both processes are joined by subjects who are in transition between these two groups. The subjects in this third group have developed *either* adult–like perception *or* high levels of phonemic awareness but have not yet developed the other process to the same high level.

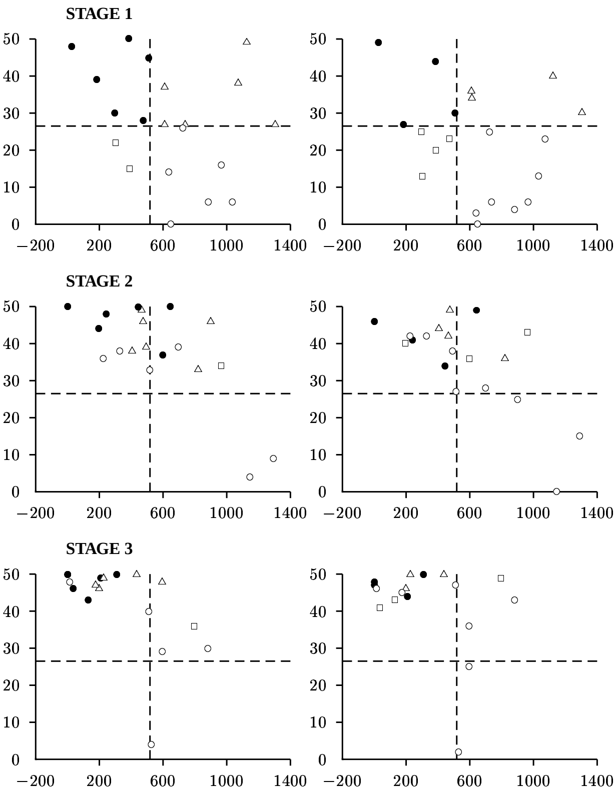

Figure 5: Scattergraphs of relationship between perception and awareness at Stages 1 (top graphs) through 3 (bottom graphs) of Experiment 1. The left graph in each pair illustrates the relationship between perceptual weighting and phoneme blending; the right graphs illustrate the relationship between perceptual weighting and phoneme segmentation.

2.4. Results

The results of Experiment 1 are illustrated in Figure 5. Each point on the graphs in this figure represents an individual child. The figures used to divide the graphs into quadrants (the adults' most "child–like" perception, in terms of separation of category boundaries, and the median phonemic awareness scores) as well as the graphical representations (open circle, filled circle etc.) for each subject, are maintained from Stage 1 through to Stage 3 so that the progress of each individual child can be tracked.

It is clear from the results of Stage 1 that the pattern of responses is not bi–modal—thus we can rule out a strictly linear relationship between perceptual weighting and phonemic awareness. Instead the responses fall into a pattern which suggests that good phonemic awareness develops before adult–like perceptual weighting.

The non–linear pattern observed at Stage 1 continues to be seen at Stages 2 and 3. Additionally, it can be seen that the children have all progressed in a manner which would support the hypothesis that good phonemic awareness develops before adult–like perceptual weighting. Specifically, those children that had displayed high levels of phonemic awareness and non–adult–like perceptual weighting at Stage 1 (triangles) develop increasingly adult–like perception at Stages 2 and 3. Those children that had displayed both low phonemic awareness and non–adult–like perceptual weighting (open circles) first develop higher levels of phonemic awareness, and then begin to develop adult–like perceptual weighting.

Statistical analyses support these observational conclusions, and also indicate that there may indeed be a possible causal aspect to the relationship between perceptual weighting and phonemic awareness. Scores on (one or both) phonemic awareness tests at Stage 1 are predictive of the separation between the category boundaries at Stages 2 and 3 (Stage 1–2: phoneme blending $r = -.56, p = .004$; phoneme blending $r = -.46, p = .023$; Stage 1–3: phoneme blending $r = -.44, p = .046$).

2.5. Discussion

The graphical results and the statistical analysis of Experiment 1 suggest that phonemic awareness both develops before and has a causal influence on the development of perceptual weighting. It is, however, possible that this is not the case. From the graphs in Figure 5, it can be seen that there are no children with strongly adult–like perceptual weighting who do not also have good phonemic awareness, which we have taken to indicate that good phonemic awareness is a precursor to adult–like perceptual weighting. An alternative explanation, however, is that adult–like perceptual weighting i) develops maturationally, and ii) is an aid to developing phonemic awareness. Any child that has adult–like perception will therefore become phonemically aware very quickly, thus bypassing an intermediate stage in which perceptual weighting is adult–like but phonemic awareness is low. The appearance of children with good phonemic awareness but non–adult–like perceptual weighting could be explained by the fact that all of the children in this experiment were being explicitly taught phonemic awareness as part of literacy training—the argument would be, therefore, that under these circumstances all of the children would develop awareness of phonemes, but those who have adult–like perceptual weighting would be at an advantage.

To test the possibility that perceptual weighting simply develops maturationally and is not influenced by the development of phonemic awareness, Experiment 2 was carried out.

3. EXPERIMENT 2

3.1. Subjects

The subjects for this experiment were 7 children from a local independent school. One of the policies of this school is that children should not begin formal education until the age of 6–7 years (one year later than state schools and other local independent schools). Additionally, this school does not begin formal literacy training until the second year of school, and while the children are introduced to the alphabet in the first year of school, no intensive phonological/phonemic awareness training is undertaken in this first year. Therefore, unless the children are taught to read outside of school, it is unlikely that they will have phonemic awareness. The average age of the children was 6 years, 11 months, and all were in their first year of full–time education. None of the children had any known hearing and/or speech disorders.

3.2. Method & analysis

The stimuli, methods of presentation and methods of analysis are as described for Experiment 1 (above). The children in this experiment were tested only once.

3.3. Results & discussion

The results of Experiment 2 are displayed in Figure 6. The figures used to divide the graphs into quadrants are those used in Experiment 1, in order that the two sets of results may be compared.

Keeping in mind the fact that the subjects in Experiment 2 are the same age (or older) than the subjects from Experiment 1 at Stage 3 of the experiment, it is clear that the development of perceptual weighting is not simply a maturational process. Leaving aside the three children who display good phonemic awareness (all of whom were receiving reading instruction outside of school, and only one of whom, incidentally, displays adult–like perceptual weighting) it can be seen that in the absence of phonemic awareness, perceptual weighting does not develop to an adult–like state.

4. GENERAL DISCUSSION & CONCLUSIONS

Two conclusions can be drawn from the results of these two studies: i) the Developmental Weighting Shift—the change in perceptual weight given to transitional and steady–state cues—is in

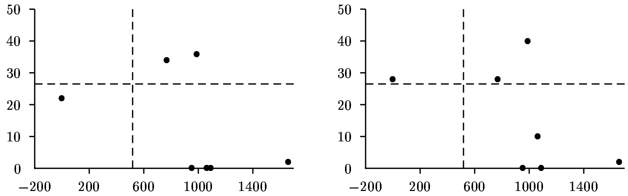

Figure 6: Scattergraphs of relationship between perception and awareness for older, (predominantly) pre–reading children. See caption of Figure 5 for further description.

fact not simply developmental or maturational. In the absence of phonemic awareness development, perceptual weighting remains non–adult–like, even in older children; and ii) in the presence of the development of phonemic awareness, perceptual weighting does become more adult–like, but it develops *later* than phonemic awareness, and is related to levels of awareness at *earlier* stages of development.

This suggests that the conscious discovery of sub–syllabic structure is important to the shift in weighting of syllable–internal formant transitions. Furthermore, the results of both experiments lend support to Nittrouer's hypothesis that perception is initially centred on a syllable–sized unit, only later to be centred on phonemes.

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