# The effect of age and reading level on perceptual weighting strategy

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## ABSTRACT

Transition and vocalic roundness is known to affect perception of the preceding fricative. The relevance of these factors were found to differ in adults and children, by Nittrouer et al [1]. We replicated part of this paradigm, and noticed that

(1) French adults and 1st graders differed, but not in the use of the same cues as English speakers in Nittrouer et al's paper [1]. We observed a developmental increase of the transition effect, and a developmental decrease in the effect of the vowel identity on the identification of the preceding fricative.

(2) We reproduced the dyslexics' well known categorical deficit, and observed that they weighted more the vowel than the transition to identify the preceding fricative, as did younger reading controls.

## 1. INTRODUCTION

Research on the perception of fricative contrasts has shown that identification of the place of articulation of the fricative is dependant on both the vocalic transition and the identity of the following vowel. In a labeling task (CP), Whalen [2] demonstrated that the boundary in a [s-S] continuum changed location according to whether the transition was appropriate for [s] or [ʃ] : more [s] response were obtained, when transition indicated a preceding [s]. The boundary location varied also in terms of vowel rounding : more [s] responses were collected when a rounded vowel followed the friction, for both types of transition. Acoustic properties of speech can account for these phenomena. Since the transition is the result of the coarticulation in the CV segment, it becomes an important cue when the listener deals with ambiguous stimuli. Moreover the anticipatory vowel's lip rounding on the preceding fricative can lower the friction frequency, which could affect the boundary location when listeners have to identify fricative-vowel syllables. Studies proved the perception of phonemic contrasts to depend on linguistic experience of the listener [1] [3]. Hazan et al [3] showed an improvement in the consistency of the categorical perception as listeners get older. Nittrouer et al's research [1] investigated more particularly age related difference in the weighting of the transition and vowel effects in fricative-vowel tokens. This work came up with a developmental increase in the weighting of both noise spectra and vowel context, whereas the effect of transition in adults was below that of children.

By systematically varying transition and vowel identity parallel to progressively increasing the noise friction frequency, Nittrouer's [1] paradigm allowed us to examine the relative weighting of acoustic cues and categorical faculties in French speaking children and adults. We also matched a group of dyslexics reading age level with the chronological age of younger good readers, to compare the relative weighting of transition and vowel according to reading group. Serniclaes et al [6], through a categorical perception task showed that dyslexics display discrimination scores below the control group level at the boundary, while scoring better than the control group for stimuli belonging to the same phonemic category. If categorical perception deficit in dyslexics is robust, we expect the control group labeling curves to be sharper than dyslexics, while the two groups should weight similarly transition and vowel information.

## 2. METHOD

### 2.1 Subjects

7 adult listeners, 17 first graders of 7 years old (average 6.10) and 17 dyslexics between the ages of 7.10 and 12.2 years, were selected to participate to the study. Reading performance was assessed with the Alouette [6] reading test. The adults were required to reach the maximum score possible in the test. The first graders reading level was superior or equal to their chronological age, while the dyslexics' was at least two years below their chronological age. The dyslexics were matched with a group of younger average readers of approximately the same reading level.

### 2.2 Stimuli

There were 4 [s-ʃ] continua differing in their transition and vowel. They all shared the same fricative portion, whose center pole frequency ranged from 3000 Hz to 6000 Hz by 300 Hz steps, yielding to 11 stimuli. The vocalic part was either [a] or [u], and in each vocalic context, the transition

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was appropriate for a preceding [s] or [ʃ].
To sum up, there were 11 stimuli * 2 types of transition * 2 vowels leading to 44 stimuli. The continua containing [s] transition + the vowel [a] or the vowel [u], will be respectively referred as [sa] and [su], while the one containing [ʃ] transition will be referred as [ʃa] and [ʃu].
To generate natural sounding fricative portion, the synthesizer we used demanded slightly different noise center pole frequencies from Nittrouer et al's parameters. Concerning the transition and the vocalic portion in the context [a], Nittrouers synthesis parameters were strictly met. Regarding [u] context, the transition and vocalic part raised a problem. The naive French listeners who pretested the stimuli, reported hearing a diphtong [yu], and a very English like syllable as well. To fix the problem we shortened the transition, so as to sufficiently indicate the place of articulation of the preceding consonant.

### 2.3 Procedure

The stimuli were presented in 4 blocks, corresponding to the 4 continua differing in transition and vowel identity. Within each block, the 11 stimuli were presented 5 times for identification in a random order. The listeners had to identify as "sa" or "sha" the stimulus presented by pressing 2 different keys of a computer. Obviously, the stimuli were presented by the experimenter as "sue" and "shue" for the 2 continua containing [u].

### 2.3 Statistical analysis

In the following analysis of the data, we chose to calculate the intercept and slope, rather than the boundary. Actually, the slope reflects the weighting of the factor on the abscissa ; and the intercept the proportion of "s" response on the hole continuum. So, in the present data, the slope will account for the weighting of fricative noise spectra, while the intercept will account for the effect of vowel and transition. As boundary depend both on slope and intercept in the present analysis, it is not a relevant statistical tool to account for the effects considered.

Individual fits of the data were performed, yielding to individual intercept and slope of each subject. An ANOVA was performed on these individual fits, with slope and intercept as between-subject factors, and age or reading group as a within-subject factor.

## 3. RESULTS

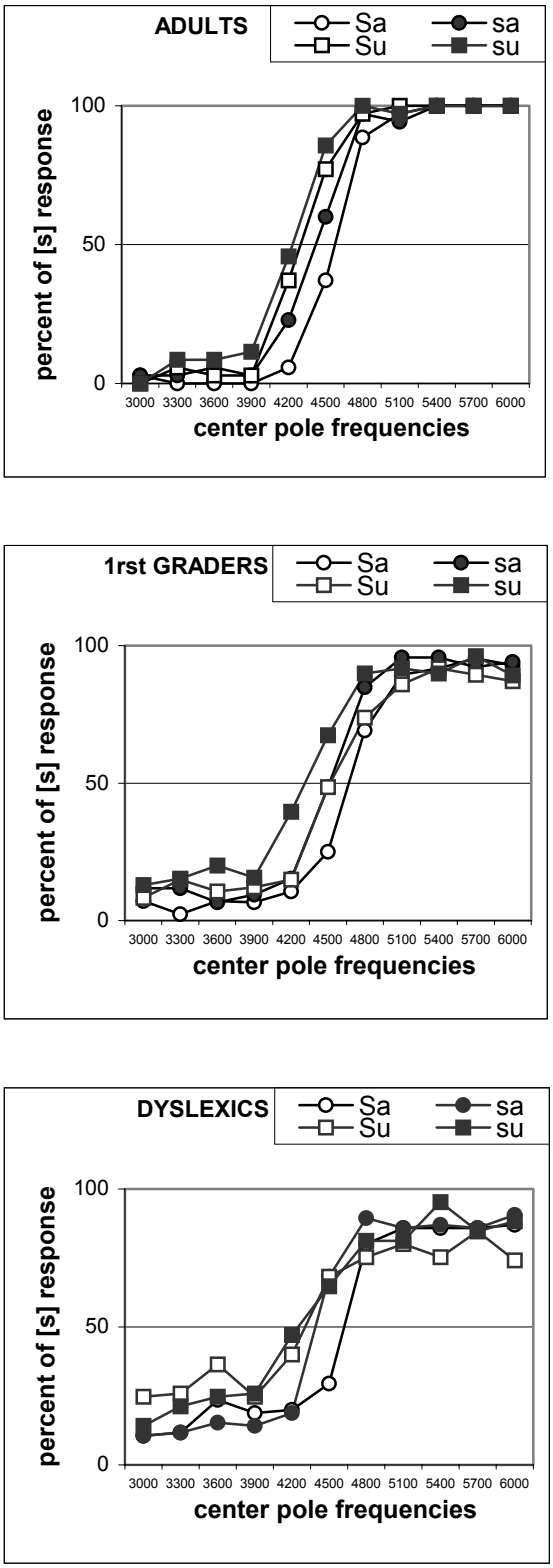


**Figure 1 : Labeling functions for adults (top), first graders (center) and dyslexics (bottom). Center pole frequencies of the fricative noise on the abscissa, and percentage of [s] response on the ordinate.**

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| | adults | 1st graders | Dyslexics |
|---|---|---|---|
| sa | 0,0046 | 0,0025 | 0,0020 |
| ʃa | 0,0065 | 0,0028 | 0,0017 |
| su | 0,0045 | 0,0020 | 0,0016 |
| ʃu | 0,0056 | 0,0020 | 0,0010 |

**Table 1 : Mean slope for each transition (s, ʃ) and vowel (a,u) contrast for adults, 1st graders and dyslexics.**

| | Adults | 1st graders | Dyslexics |
|---|---|---|---|
| sa | -20 | -11 | -8 |
| ʃa | -29 | -13 | -7 |
| su | -19 | -8 | -6 |
| ʃu | -23 | -9 | -4 |

**Table 2: Mean intercept for each transition (s, ʃ) and vowel (a,u) contrast for adults, 1st graders and dyslexics.**

### 3.1 Adults - First Graders

The general effects of transition ($F(1;22)= 6.282$ $p<0.05$) and group ($F(1;22)= 23.490$ $p<0.01$) are significant for the slope. So the weighting of fricative noise differ across groups : adults slopes are far superior to 1st graders (table 1). Moreover the weighting of noise friction information differ according to the transition. Adults seem predominantly responsible for this last effect, given that they are the sole group to exert a significant effect of transition ($F(1;6)= 5.510$ $p<0.057$), and comparison across the 2 groups indicate a significant group*transition interaction ($F(1;22)= 8.733$ $p<0.01$).

The general effects of transition ($F(1;22)= 7.195$ $p<0.05$) and group ($F(1;22)= 22.013$ $p<0.01$) are also significant for the intercept. Mean intercept across the two groups are larger in children, which shows that children tend to answer many more times "s" compared to adults. As above, adults seem responsible for the transition effect. It is significant in adults ($F(1;6)= 5.966$ $p<0.05$), not in 1st graders ($F<1$) and the group*transition interaction is significant ($F(1;22)= 9.251$ $p<0.01$). As expected, the transition effect is greater when appropriate for a preceding [s].

The general effect of vowel was non significant ($F<1$), as the group*vowel interaction ($F<1$). Nonetheless, 1st graders demonstrated a significant effect of vowel on slope ($F(1;16)= 4,280$ $p < 0,05$) and intercept ($F(1;16)= 4,680$ $p < 0,05$), while adults did not. Interpretation of vowel effect on 1st graders performances is discussed further in the following section.

### 3.1 First Graders - Dyslexics

The vowel effect is significant for both groups for the slope ($F(1;32)= 6,064$ $p<0.05$) and the intercept as well ($F(1;32)= 6,426$ $p<0.05$). No other effect or interaction were significant. In 1st graders and dyslexics slopes are sharper in the "a" context (Table 1). The vocalic context affected the intercepts as well (Table 2). The mean intercepts are inferior in "a" than in "u" context. Then, the vowel effect expected is exerted by dyslexics and the control group, while the transition effect is not significant ($F<1$).

## 5. DISCUSSION

Regarding the increase in the weighting of the noise friction information from children to adults, we replicated the well known age effect on categorical perception. Hazan et al [3], observed that children exerted a less categorical pattern of performance than adults. Moreover, they noticed a developmental improvement of categorical perception from 6 to 12, and concluded that linguistic experience increases the consistency of the phonemic categories of the listener. Although the dyslexics were older than the controls, they did not show any improvement in the identification of the place of articulation of the fricative compared to the control group.

Vowel rounding is known to affect the identification of ambiguous noise friction [2]. In a [s-ʃ] continuum more "s" response were collected when the following vowel was rounded, than when it was not. This lowering of the boundary was accounted for the anticipation of the lip rounding of the vowel on the preceding fricative, that should lower the noise spectrum in normal speech. We failed to replicate this effect on adults. On the other hand children's performances were influenced by the vowel rounding. As in previous experiments, the children's proportion of "s" response was greater in the rounded vocalic context ([u]) than in the unrounded one ([a]). Consequently, children relied more strongly on the noise friction when the vowel was unrounded, given that in normal speech unrounded vowels are not supposed to affect noise spectra frequency.

Unlike the vowel effect, the transition effect was significant in adults but not in children. The weighting of noise differed across transition in adults, so that they paid more attention to noise friction when the transition indicated a preceding [ʃ]. Dorman [8] noticed also an asymmetric influence of transition on the weighting of occlusive burst spectra. As the shortest transitions led to an increase in the weighting of the burst, the author accounted for this as a strategy permitting the listener to weight the transition when it is the most informative. In our study, it is relatively hard to determine the most acoustically salient transition, given that their duration was equal and the magnitude of formant frequency difference for [s] and [ʃ] were equivalent.


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As Nittrouer et al [1], we noticed developmental changes in the use of acoustic cues to identify the fricative place of articulation, but this developmental trend is contrary to Nittrouer et al's results. We won't discuss the language related differences between Nittrouer and the present study. In the first place, we want to evaluate the effects natural occurrences of French transition + vowel segment, to control the present synthetic stimuli.

The performance in the categorical perception of the fricative continuum in dyslexics are inferior to the control group. This is consistent with preceding research ([4] [5]), suggesting that the deficit in categorical perception is responsible for the dyslexics reading delay. According to these investigations, categorical perception deficit points out the lack of robustness of dyslexics phonemic categories also noticeable in the difficulty these children experience in phonemic segmentation tasks. To successfully achieve reading acquisition, a child must be able to automate the grapheme-phoneme connection. In dyslexics, the inconsistency of the phonemic representation prevent them to establish reliable grapheme-phoneme connection, which give rise to specific reading difficulty. Dyslexics deficit not only lies in less accurate discrimination of stimuli straddling the phoneme boundary but also in a better perception of stimuli belonging to the same phonemic category and differing in their acoustic properties [5]. Hence speech deficit in dyslexia resides in a weaker ability to discriminate phonemically distinct stimuli, associated with an increased discrimination of phonetically differing stimuli though not phonemically contrastive. Given that non phonemic acoustic variants are as pertinent as phonemic opposition in dyslexics, the phonemic representation connected to the grapheme is more complex than in normal readers, and consequently affects reading performances.

The other problematic brought up by this experiment was how dyslexics would weight cues and features assigned to the blurred phonemic categories they display. Dyslexics were all older than 1st graders (see section 2.1). As dyslexics made use of vowel and not transition to weight the friction, their performance seem immature given that they performed similarly to 1st graders and did not take into consideration the transitional cue adults weighted predominantly. This phenomena gives credit to a speech perception deficit in dyslexics, as their categoricalness and weighting strategies are conditioned and hence limited by their reading ability. To control further this assumption we plan to compare the dyslexics to chronological age control group, which would allow us to ensure that dyslexics' weighting strategy differ from age controls. Furthermore, these result also question the influence of reading acquisition on categorical perception improvement, and as revealed by this study its influence on weighting strategies of contextual speech information. To clarify this point, data need to be collected on illiterate adults, and a longitudinal study must be done before and after reading acquisition as well.

## 4. CONCLUSIONS

This study has provided experimental data replicating the developmental trend in the weighting of speech acoustic cue, while raising the question of the nature of the developmental changes in cue weighting strategy. Moreover, the dyslexics' speech perception deficit has been shown to be reflected by a weak categorical perception and immature weighting cue strategy, which can account for the reading deficit they display.

## ACKNOWLEDGEMENTS

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