

The effect of age and reading level on the perception of temporal speech information

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ABSTRACT

In a previous experiment Carré et al. showed that perception of a synthetic [ai] token depends on the duration of the transition between the two vowels. French adults reported hearing either /ai/ or /aei/ depend on whether the duration was below or above 200 ms. This perceptual threshold is also the mean duration of a syllable in French. Carré et al. assumed that the syllabic analysis of the speech input by French listeners may influence the perception of the transition, leading to the perception of /aei/ when the transition duration is longer than 200 ms. The present data indicate that the durational threshold for perceiving three vs. two vowels in VV tokens depends both on the age and reading level of the listener.

1. INTRODUCTION

Carré et al [1] studied the effect of lengthening the transition in VV tokens. French listeners reported hearing /aei/ for transition durations longer than 200 ms, shorter transitions being perceived as /ai/. Carré et al. [1] explain these results as follows. First, in normal speech the transition standing between [a] and [i] crosses the formant values of the vowel [e], which explains that the extra sound perceived was /e/. Second the syllabic structure of French could account for the 200 ms threshold given that this value corresponds to the average duration of a syllable in French.

Different experiments [2] [3], showed that the perception of phonemic contrasts depends on the age of the listener. To see whether age also affects the perception of an extra vowel in VV stimuli, we proposed Carré et al's protocol to children aged 6, 7 and 13. The data collected will allow us to see whether perception of /aei/ becomes closer to the adult pattern of performance as the listener get older. We assumed that to perceive the extra sound, the younger the listener is, the longer transitional duration must be. Such a result would support the assumption that perception of the stimuli is partly conditioned by linguistic experience.

Recent research [4] [5] showed dyslexics to have a deficit in categorical perception of speech sounds. It has been argued that the lack of consistency of dyslexics phonemic categories might play a causal role in their reading deficit by affecting the acquisition of grapheme-phoneme correspondences [6]. The categorical perception deficit

might also affect the segmentation of speech sounds into phonemes categories if information required for accessing to phoneme representation has to be collected over a longer time interval when categorical representations are less robust.

2. METHOD

2.1 Subjects

3 groups of children participated to the experiment : 36 aged 13 and 34 followed longitudinally from 6 (non readers) to 7 (1st graders) years old. At 13 y-o, 19 children scored at least 2 years below their chronological age at the Alouette reading test [7], and were consequently referred to as the dyslexic group. The 17 remaining average readers participated to the experiment as controls.

2.2 Stimuli

6 "[a]+transition+[i]" token, were presented to the listeners. The vocalic parts were constant whereas the transition duration varied from 50 to 300 ms by 50 ms steps. The vowel [a] lasted 100 ms, and F1, F2 and F3 started at 743, 1543 and 2796 HZ. The vowel [i] lasted 150 ms and the first three formant ended at 240, 2500 and 3140 HZ. Formants F4, F5 and F6 were fixed at respectively 2800, 4500 and 5500 HZ.

2.3 Procedure

The 6 stimuli were presented 10 times in isolation at random order, yielding to 60 presentations. They were presented through headphones at a comfortable level via a PC. The listeners identified the stimuli by pressing keys of the computer's keyboard, tagged with the numbers "2" and "3". The listeners had to press "2" or "3", according to they perceived 2 or 3 sounds. When the task was over, listeners had to report what they heard when responding, to ensure they heard /ai/ and /aei/.

2.4 Statistical treatments

The data were analyzed by Logistic Regression, which provides valuable estimations of the slope and intercept, of S shaped identification curves. The slope gives the rate at which this switch occurs while the intercept reflects

tendency to answer "ai" irrespective of transition duration. The boundary, which corresponds the transition duration at which "ai" responses reach 50%, is obtained by dividing the intercept by the slope (boundary = -intercept/slope). Although commonly used for comparing identification curves in various studies, the boundary is a complex parameter which depends both on the sensitivity to the acoustic continuum under study and on the response bias. Only statistical comparisons between groups will therefore be performed on intercept and slope values. Boundary values will only be given for indicative purposes.

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 level as a within-subject factor.

3. RESULTS

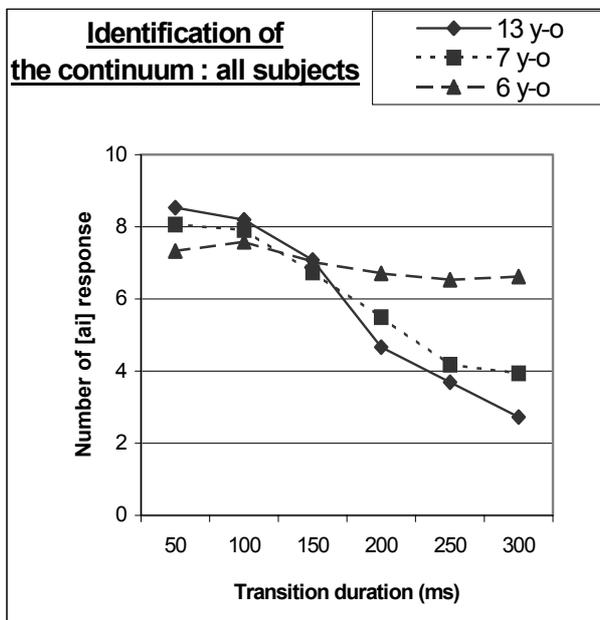


Figure 1 : Identification performance of the [ai] continuum for all the subjects (13, 7 and 6 y-o) and each transition duration ranging from 50 to 300 ms

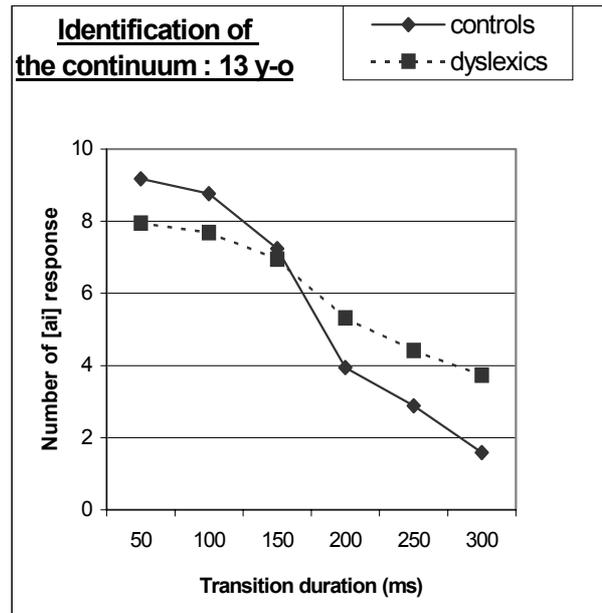


Figure 2 : Identification performance of the [ai] continuum for the 13 y-o dyslexics and controls, each transition duration ranging from 50 to 300 ms

3.1 All subjects

	Boundary	Slope	Intercept
13 y-o	209 ms	- 0.012	2.53
7 y-o	231 ms	- 0.008	1.97
6 y-o	613 ms	- 0.002	1.17

Table 1 : Results of the linear regression : Boundary, slope and intercept, for each age group.

All subjects reported hearing either /ai/ or /aei/ or both. Individual fit of the data required to remove non S-Shaped individual identification functions. This led to the removal of 2 listeners in the 7 years old group, and 10 in the 6 years old group. The following analyses were performed on all 13 years old good readers and on 7 and 6 year olds without non categorical listeners. Mean values for intercept, slope and boundary are presented in Table 1.

Identification performances for each age group are presented in Figure 1. The boundary exerted by the 13 years old group is 209 ms (Table 1), hence is located around the same duration as in Carré et al. study on adults.

The younger subjects, aged 6 and 7, needed longer transition duration to switch from "ai" to "aei" response. Between the 3 groups of children in the present study, we can observe a developmental trend in the location of the boundary : the younger the listener the longer the duration

boundary. These boundary differences arise from a twofold change in both the slope and the intercept of the labeling curves. The odd boundary value for 6 years old is due to the relatively flat curve they exhibit : as they mainly answer "ai" whatever the transition duration, 50% of "ai" response is never reached. The shift of the boundary towards *shorter* durations between 7 and 13 years old is due to a steeper slope and occurs despite an increase in the response bias towards "aei" responding, which has a *lengthening* effect on the boundary location.

The reduction of the intercept value indicates that the older the listener, the more "ai" response they give. The smaller intercept exerted by younger listener indicates a stronger bias toward the perception of /aei/ irrespective of the transition duration.

The effect of age is significant both for the intercept ($F(1,48)=3.07$ $p<0.05$) and for the slope ($F(1,48)=10.83$ $p<0.01$). The planned comparison 13 y-o versus 7 y-o and 7 y-o versus 6 y-o, showed that both differences are significant for the intercept (13 vs 7 y-o $F(1,47)=7.6$ $p<0.01$, 7 vs 6 y-o $F(1,47)=4.01$ $p<0.05$), while slope was non significant (both comparisons $F<1$).

As the intercept reflects the bias towards "ai" responding irrespective of transition duration, age differences reflect the transition duration effect increases in consistency from young to older listeners.

3.2 13 y-o : Dyslexics vs. controls

	Boundary	Slope	Intercept
13 y-o controls	195 ms	- 0.017	3.46
13 y-o dyslexics	230 ms	- 0.008	1.90

Table 2 : Results of the linear regression : Boundary, slope and intercept, for each age group.

The regression performed on the 13 years old data showed that both the slope and the intercept of the labeling functions differed between dyslexics and controls (Table 2). The mean slope is shallower for dyslexics vs controls (Figure 2). The intercept is lower for dyslexics, which indicates that the bias towards "aei" responding is larger than for controls. Dyslexics need longer transition duration to perceive /aei/ as indicated by the location of their boundary. It is noteworthy that the dyslexics mean values (Table 2) are very similar to 7 years old groups (Table 1).

The effect of reading level was significant on slope ($F(1,34)=17.86$ $p<0.01$) and intercept ($F(1,34)=9.04$ $p<0.01$).

4. DISCUSSION

Carré et al [1], explain the effect of transition lengthening on the perception of three vs. two vowels by stating that listener make a syllabic analysis of the speech input, and reset the trace of the auditory information when the transition exceeds the usual syllable duration. When transition is shorter than 200 ms, a single syllable is perceived (/ai/). For longer transitions, an extra syllable is perceived, i.e. transitions lasting more than 200ms are perceived as /e/.

The present data reveal an effect of age and reading level on the duration required for perceiving an extra vowel. These differences arise from changes both in the sensitivity to transition lengthening and in the bias towards the perception of two vs. three vowels in V-V sequences.

4.1 Age related effects

Those data tend to show a developmental trend in the detection of the 200 ms threshold. Linguistic maturation helps listeners adjusting the identification of the 3rd sound in adequacy to the syllabic parameter as Carré's adults. Second, the transition seems to become a more consistent cue as the listener gains in linguistic experience.

The effect of transition duration on the perception of /ai/ and /aei/ differed as function of the listeners age. 13 years old compared to 7 years old, and 7 years old compared to 6 years old rely more strongly on the transition duration to identify the stimuli. As older children switch from one category to another more rapidly, transition is less ambiguous to them.

6 year olds do not rely at all on the syllabic parameter and only perceive /ai/. While one year later, the same subjects are able to make use of the duration to identify the transition according to the syllabic parameter. This might be due to various developmental changes including reading acquisition. Linguistic maturation effect on the perception of the extra sound is twofold. Firstly, it affects the ability to rely on the syllabic parameter : the more linguistically mature listeners are more aware of the relevance of the syllable to partition speech signal. Secondly, language acquisition improves the phonemic consistency of the extra phoneme percept. Numerous studies [3] on cue weighting strategies, showed adults weight acoustic property as function of its relevance in a given phonetic context, while children do not make use of contextual factors to perceive phonetic information. Following this assumption, linguistic development influences perceptual strategies by teaching the listener how context and phonetic properties co-vary. The developmental effects revealed in the present results might arise from changes in segmentation processes. Linguistically experienced listeners might use vocalic transitions to parse the stimuli in syllabic units, in accordance with the average duration of a syllable in French. At 7 years old, listeners already make use of the transition duration but have not yet learned how to adjust

their percepts to syllabic duration.

The present results are also consistent with studies on the development of categorical perception which showed that phonemic consistency improved from childhood to adulthood. The present results show 6 and 7 years old response was less accurate than 13 years old group, because they relied less strongly on the transition, and transition labeling was less consistent.

4.2 Effects of reading level

The results for 13 years old children indicate that dyslexics were less consistent in the processing of the transition duration, as shown by the shallower slope of their labeling curve. Furthermore, dyslexics tend to give more "aei" responses, irrespective of transition duration. These effects can be related to the phonemic segmentation and categorical perception deficits which have been evidenced for dyslexic children.

Dyslexics are known to experience a specific reading trouble. Studies on dyslexia have shown that speech processing is also impaired in dyslexics. They suffer from phonological segmentation difficulties, as well as categorical perception deficit. These investigations helped understanding how speech processing can account for reading performance. In reading, one have to connect the smallest units in writing "the grapheme", with the "smaller" units of speech "the phonemes". When this connection is automated, the reader has achieved reading acquisition, and becomes a fluent reader. Some experiments showed that dyslexics phonological device is impaired, because their phonological categories seem to be less well constituted and less consistent than average readers of the same age. So when reading, the dyslexic cannot establish an efficient grapheme-phoneme connection, as the grapheme refers to a weak phonemic category. In the present experiment, the detection of the phoneme /e/ is shown to require a longer transition duration in dyslexics than in controls because of different factors. Firstly, they rely less strongly on the transition information to identify it : this can be explained by the lack of consistency of their phonemic categories which prevent them to use accurately the transition for perceiving phonemes. Secondly, dyslexics exhibit a stronger bias towards the perception of the extra /e/ vowel. This response bias can be related to another study showing that dyslexics tend to perceive allophonic categories in discrimination tasks [8]. A larger vocalic repertoire would increase the probability of perceiving an extra vowel irrespective of transition duration, thereby explaining the response bias found here.

Finally, our results raise the question of the perception of temporal information in speech. Dyslexics have been shown to experience difficulties in processing rapid succession of auditory stimuli [9]. Even though dyslexics need longer transition to perceive the extra sound, this deficit can be accounted for by speech processing deficit.

5. CONCLUSIONS

The perception of the transition according to the syllabic parameter, is shown to depend on age and reading level. These results are consistent with recent hypothesis assuming phonemic consistency improves from childhood to adulthood, and that dyslexics exert speech processing deficits.

ACKNOWLEDGEMENTS

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