Relation between categorical perception of speech and reading acquisition

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ABSTRACT

Data before and after reading acquisition were collected in order to study the influence of linguistic experience and literacy on the emergence and consistency of categorical perception (CP). Children aged 6 and 7 years identified and discriminated [do] and [to] syllables from a VOT continuum. The same paradigm was proposed to 10 years old children. The latter were subdivided according to their reading performance to assess whether categorical perception is impaired in poor readers. From 6 to 7 categorical perception improved. As subjects differed both in age and reading experience, these data bring out the question of the relation between linguistic maturation and literacy. Poor readers were less accurate in the discrimination of phonemically contrastive pairs. On the contrary they performed better than controls for the discrimination of phonemically irrelevant contrasts. The origin of the categorical deficit displayed by poor readers, and its possible influence on reading performance is discussed.

1. INTRODUCTION

Acoustic differences between variants of the same phonetic category are generally not perceived, whereas differences of the same acoustic amplitude between sounds belonging to different phonetic categories are perceptible. This phenomenon is known as categorical perception (CP) [1]. French stops differ according to the Voice Onset Time (VOT) from -100 ms for voiced stops to + 30 ms for voiceless ones [2]. In French, the perceptual voicing boundary is generally localized around 0 ms. Therefore, we expect labeling response to switch from "do" to "to" at around 0 ms. To the extend that perception is categorical, listeners should only discriminate stimuli straddling the 0 ms VOT value. Investigations on the perception of different phonemic features [3] showed that linguistic experience improves categorical perception consistency. The aim of the present study is to obtain further evidence on both the effect of age and reading level on categorical perception. From 6 to 7, listeners should display skewer identification functions, and increased discrimination scores at the boundary. Labeling and discrimination data were collected in different groups of children for stimuli varying along a VOT continuum. The interest of the VOT continuum is that it encompasses different perceptual boundaries.

VOT measurements in various languages allow splitting initial stops into three main categories, the first characterized by the onset of voice before the release of the closure (by voice lead or negative VOT), the second by a short lag between the release and voice onset (by a short voice lag or a short positive VOT) and the third by a long lag (by a long voice lag or a long positive VOT)[4]. The three VOT categories are phonemic in some languages, such as Thai. Other languages, among which English and French, only use two VOT categories for distinctive purposes.

Cross-linguistic variation in the production of VOT is matched by a similar variation in perception. Cross-linguistic comparisons suggest that three different boundaries are used for segregating VOT categories in the world's languages. A boundary located at some -30 ms VOT allows to segregate prevoiced stops from those with a short voicing lag. Symmetrically, a +30 ms VOT boundary allows to segregate stops with a short voicing lag from those with long voicing lags. Studies on the perceptual capabilities on the newborn suggest that children below 6 months of age are sensitive both to the negative and the positive VOT boundaries, irrespective of the language background [5,6]. For children raised in two-category languages, only the sensitivity to the adult VOT boundary is kept after about 6 months of age [7,8].

To the extend that age and reading level differences in CP reflect developmental changes in the use of language-specific boundaries, we expect to find related differences in the sensitivity to the voicing boundaries. Specifically, we expected to obtain a better sensitivity to the phonemic boundary for older children as well as for those with a high reading level. Conversely, we expected the sensitivity to allophonic boundaries to be better for younger children and for those with a low reading level. Serniclaes et al. [9] showed dyslexics were less accurate than controls for discriminating between-category stimuli. However dyslexics were better than average readers for perceive acoustically distinct stimuli that were phonemically similar. Categorical deficit in poor readers is expected to be replicated, as the discrimination of between-category stimuli should be less accurate than controls. The present experiment aims at evaluating whether Serniclaes et al results could be accounted by an inefficient deactivation of innate perceptual predispositions noted by Werker [10].

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2. METHOD

2.1 Subjects

A group of 36 children were tested twice, before and after reading acquisition. Participants were monolingual French native speakers, who did not experience any auditory deficit, and showed a normal verbal and non verbal IQ. When first tested, children were 6 y.o and did not succeed in the Batelem reading test. When retested at 7, subjects were readers. Transversal data were also collected on 10 y.o children. They were subdivided according to their reading score at the Alouette test [11]. Good readers reading score were equal or above their chronological age, while poor readers scored at least 18 months below their chronological age.

2.2 Perceptual tests

2.2.1 Material

A VOT continuum ranging from – 50 to + 50 ms was obtained by :

1. pasting a 50 ms prevoicing segment extracted from a French [do], before the release of an English [do].
2. reducing the prevoicing by 10 ms steps.
3. progressively replacing the post release segment by aspiration extracted from an English [to] in five 10 ms steps.

2.2.2 Procedures

Listeners were asked to identify and discriminate the [do]-[to] continuum. The 11 stimuli were presented 10 times randomly and were identified as [do] or [to] by pressing the appropriate key on a computer keyboard. In the discrimination task, stimuli were presented in 2 steps pairs (differing by 20 ms) repeated 8 times at random order. Listeners were asked to indicate whether the pairs presented were identical or different. The results was analyzed in terms of percentage correct discrimination scores. For each stimulus pair, these scores were obtained by computing the mean percentage of "different" responses to pairs of acoustically different stimuli (e.g S0 S20) and "same" responses to pairs of identical stimuli (e.g S0 S0 and S20 S20) by the different subjects.

3. RESULTS

Both identification and discrimination results were tested by an ANOVA . To compare 6 to 7 y.o, a repeated measure ANOVA was run with VOT and age group as within subject factors for identification responses, and VOT pairs and age group for discrimination scores. To compare good vs poor readers in the 10 y.o group, one factor ANOVA was performed on the results with reading group as a between subject factor and VOT pairs as a within subject factor. A t-test was run to see which pair was discriminated above chance level (50%).

3.1 7 years old compared to 6 years old

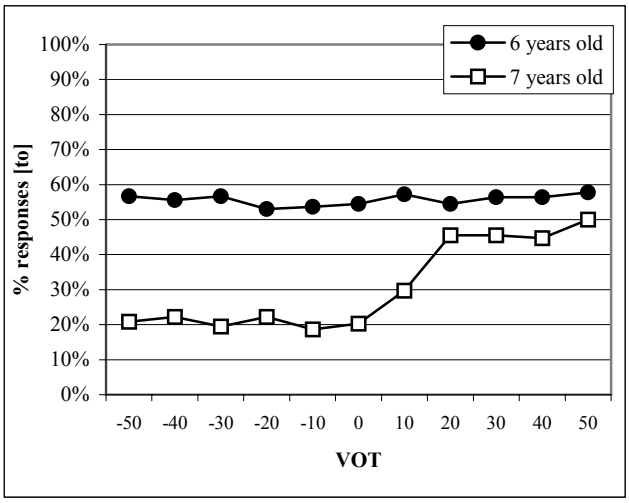

Figure 1 : identification scores of the 6 and 7 y.o children.

The general effect of age ($F(1,35)=11,36$ $p<.01$) and VOT ($F(10,350)=12,63$ $p<.01$) were significant in the identification task, as well as the age*VOT interaction ($F(10,350)=10,26$ $p<.01$). As seen Figure 1, the effect of age can be seen on labeling performance arises from the skewless identification function at 6. Although response never reach 50% in any group, the slope at 7 is skewer than at 6.

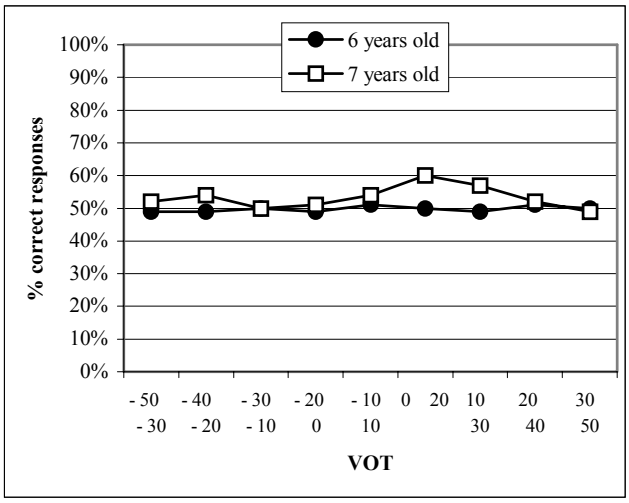

Figure 2 : discrimination performances at 6 and 7 y.o.

Effects of age ($F(1,35)=18,401$ $p<.01$) and VOT pairs ($F(8,280)=3,53$ $p<.01$) on discrimination scores were also significant. The discrimination function was flat at 6 years whereas two discrimination peaks were present at 7 years. T-test showed 7 y.o discriminate above chance level the pair S-40 / S-20 ($t(35)= 3,52$ $p<0.1$), as well as those between S-10 and S30 (S-10 / S10 $t(35)=2,26$; S0 / S20 $t(35)=4,19$; S10 / S30 $t(35)=2,43$; all $p<.01$).

3.2 Poor readers compared to good readers

The effect of VOT was significant on the labeling performance ($F(10,190) = 12,41$ $p<.01$), as well as the VOT * reading group interaction ($F(10,190)= 5,26$ $p<.01$), while the effect of reading group was non significant ($F<$

1). The absence of group effect can be attributed to the fact that poor readers exerted an almost flat labeling function.

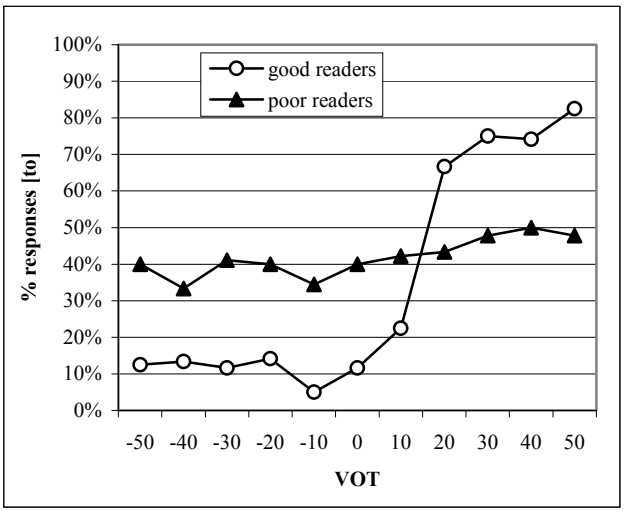

Figure 3 : identification scores of good and poor readers

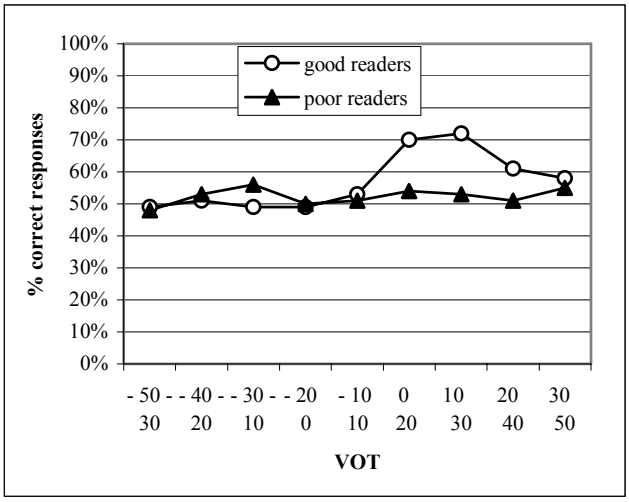

Figure 4 : discrimination performances for good and poor readers.

For the discrimination data, the general effect of VOT was significant ($F(8,152)=8,29$ $p<.01$), as was the effect of reading group ($F(1,19)=4,29$ $p= 0,05$) and the VOT pairs*reading group interaction ($F(8,152)=6,16$ $p<.01$). T-tests showed that poor readers discriminated the pair S-30 / S-10 above chance ($t(8)=4,53$ $p<.01$), while good readers discriminated those ranging from S0 to S30 (S0 / S20: $t(11)=5,78$ $p<.01$; S10 / S30: $t(11)=5,80$ $p<.01$).

4. DISCUSSION

The paradigm presented in this paper allows us to evaluate the perception of native and non native contrasts in listeners differing in their linguistic experience, literacy and reading level.

The first hypothesis assuming linguistic experience affects categorical performance is validated by the longitudinal data collected at 6 and 7 y.o. The latter displayed more consistent identification function, and discriminated pairs of stimuli straddling the predicted phonemic boundary. Poor readers exhibited categorical perception deficit better discrimination within categories, and lesser discrimination between, confirming the second hypothesis. Good readers discrimination peak was located at the phonemic boundary, while poor reader one involved phonemically irrelevant VOT values.

At 6, the criteria defining CP were not met, although previous experiment showed CP in 6 months infants [10]. This result can be explained by a floor effect caused by the task demand. The present paradigm requires the subject an explicit response (pressing keys of a computer) to an overt judgment (same – different). When aiming at showing group differences, methodological constraints need the task demand to be adapted to the subject ability. The paradigm proposed was adequate to 7 y.o, while lying beyond 6 y.o ability. Although 6 y.o group did not perceive the continuum categorically, the emergence of two peaks at 7 seems to indicate that linguistic experience helped them use more efficiently their speech perception skills to detect the phonemic categories constituting the continuum.

Werker et al. [10] suggested infants aged 6 to 12 months are born with the ability to distinguish all phonetic contrasts of world languages. This predisposition would be maintained or neutralized according to the relevance of the contrasts in the listener linguistic environment. This phenomenon can account for the intra-phonemic discrimination peak displayed by 7 y.o. Given that the pair S-40/S-20 straddles phonemic boundary relevant in Thai, the fact that 7 y.o still discriminate this pair reflects the persistence of the activation of non native contrasts. This has also been evidenced for adults when processing sound at the phonetic level. Werker [12] noted that phonemic level of processing involved in native contrasts perception is much salient than phonetic level, which explain the stronger discrimination peak at French boundary than the one at Thai boundary in 7 y.o.

6 and 7 y.o groups differed in age, but also in literacy. As will be further discussed below, categorical perception deficit seems to be related to low reading performance, as CP performances were dramatically worse in poor readers in number of studies [9]. These results raise the question of the causal relation between reading and perception. By taking this suggestion into consideration, age effect might not solely account for the improvement of categorization from 6 to 7, but reading acquisition could also participate to the increase in consistency of phonological categories. In this experiment, poor readers performances differed from good readers in two ways : first they exhibited lower discrimination scores at the boundary; second they exhibited another peak at different VOT values. The categorical deficit in poor readers is well documented [9,13], and was shown to be related to their reading delay. Reading in an alphabetic system demands the reader to establish a connection between reading unit named grapheme, and speech units the phonemes. Fluent readers have automated the grapheme-phoneme correspondence. Given that this correspondence is the core device in the reading process, it essentially depends on the phonemic categories reliability [14]. In poor readers, phonemic

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categories are less robust than controls, as displayed by lower discrimination scores at the boundary. This can account for their reading delay, as their reading device would rely on inconsistent grapheme-phoneme correspondence. Serniclaes et al [9] investigated further this deficit in categorical perception, by putting forward poor readers were able to perceive variants of the same phonemic category differing in their phonetic propriety, while they were impaired in discriminating phonemically different stimuli. In the present experiment we aimed at investigating further poor readers ability to perceive non relevant contrasts. Good readers exerted a phonemic boundary at the predicted values, while poor readers discriminated stimuli belonging to the same category, thereby confirming the previous results. Further, the present data suggest that poor readers categorical deficit explained desinhibition of native predispositions for perceiving phonetic distinctions. This assumption is supported by poor readers results, as they did not discriminated the stimuli differing in VOT values relevant in French, but located the boundary at VOT values supposed significant in Thai speakers [15]. Thus, we can state that poor readers deficit not only stand in a lower phonemic discrimination, but also in a better discrimination of non relevant contrasts, that could be caused by a lack of desinhibition of non native contrasts. This assumption is further supported by the fact that 10 y.o poor readers discrimination peak is also noticeable in 7 y.o.

4. CONCLUSIONS

Following the present results, categorical perception of speech sounds seems to depend on language and literacy maturation. Poor readers discriminated stimuli not straddling the French phonemic boundary : this could be the result of an ineffective desinhibition of an innate predisposition, leading poor readers to perceive non relevant contrasts in French.

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