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Effects of Voicing Similarity Between Consonants in Printed Stimuli in Normal and Dyslexic Readers

Sonia Krifi, Nathalie Bedoin and A. M rigot

Accumulated data have provided evidence for the main role of phonology in printed word recognition (for reviews, see Berent & Perfetti, 1995 ; Frost, 1998). In priming experiments, phonetic features have been shown crucial units for print processing (Bedoin, 1998). In the high phonetic similarity condition, initial phonemes of a prime and target stimulus pair shared two phonetic properties, for instance voicing and manner (e.g., *don* - *BON*) ; in the low phonetic similarity condition, the pair shared only one phonetic property (e.g., *ton* - *BON*). We found that the additional similarity in voicing in the high phonetic similarity condition negatively affected response latencies in lexical decision, whatever the SOA (100, 66, 33 ms), frequency and lexical status (word or pseudoword) of prime and target.

To account for longer latencies in case of high phonetic similarity, reading was assumed to be affected by phoneme detectors organised in terms of phonetic properties shared by phonemes (Bedoin, in revision). The greater the number of phonetic properties shared by two phonemes, the stronger the lateral inhibition between corresponding units. So, if /d/ is identified in the first stimulus (e.g., /d /), this may inhibit the response to the initial phoneme in the following stimulus /b /, because /d/ and /b/ share many phonetic features. If /t/ is identified in the first stimulus (e.g., /t /), this may inhibit, to a lesser degree, the /b/ in the following /b / because /t/ and /b/ differ in many phonetic properties (i.e., place and voicing).

According to this interpretation, the opposite effect was expected in backward masking, where the printed target is presented first and replaced immediately (masked) by another stimulus. The subject has to recall the target, which is difficult because of the mask, that disrupts the target processing. This disruptive effect is

known to be reduced in case of orthographic or phonemic overlap between target and mask (Perfetti & Bell, 1991). We showed that phonetic similarity also reduced deleterious masking effects (e.g., *DÉBUT* was better identified if masked by *zévut* than by *séfut*) (Bedoin & Chavand, 2000). Identification of consonants in the target was assumed to inhibit phonetically similar phoneme detectors, which may impair the mask identification and reduce its disruptive effect. To sum up, voicing similarity between two sequentially presented stimuli reduces performances on the second one, and improves the processing of the first one in reading.

Phonetic priming effects have been replicated with other phonetic classes, but voicing similarity provided the most extensive effects (Chavand & Bedoin, 1998). Place or manner similarity resulted in non-linear priming effects across SOAs, increasing response latencies with 66 and 100 ms-SOAs, but reducing them with a 33 ms-SOA. Noteworthy, Lukatela, Eaton, Lee and Turvey (2000) also found shorter response times in case of phonetic similarity with a 57 ms-SOA, which is in accordance with our data since place and manner (not voicing) similarity was manipulated, with a SOA shorter than 66 ms. Non-linear effects restricted to place and manner similarity suggest that inhibitory relations between phoneme detectors are established on different tiers, depending on phonetic classes. Some tiers may be accessed more directly than others, and organisation based on voicing similarity may be privileged in French. Therefore, prime-target voicing similarity should trigger inhibitory effects sooner than similarity in other phonetic properties. With short SOA, place and manner phonetic properties may simply be extracted from the first printed stimulus and pre-activate phoneme detectors sharing these properties, resulting in a classical facilitative priming effect in the high similarity condition.

This research¹ investigated the sensitivity of dyslexic children to voicing similarity in reading. It is usually accepted that dyslexic children are impaired in phonological skills (Joanisse, Manis, Keating & Seidenberg, 2000). Poor phonemic awareness (Duncan & Johnston, 1999) and impaired phonological short-term memory (Brady, Shanweiler & Mann, 1983 ; Liberman, Mann, Schankweiler & Werfelman, 1982) are described, as well as deficits in categorical perception of phonemes (Manis et al., 1997 ; Mody, Studdert-Kennedy & Brady, 1997 ; Werker & Tees, 1987) due to an increased perceptibility of acoustic differences within phonemic categories (Godfrey, Syrdal-Lasky, Millay & Knox, 1981). According to the auditory model, dyslexic persons are impaired in rapidly changing sounds processing (Tallal, 1980), whereas the deficit is speech specific according to the phonetic model (Rosen, 2003 ; Rosen & Manganari, 2001 ; Serniclaes, Sprenger-Charolles, Carré & Démonet, 2001 ; Studdert-Kennedy & Mody, 1995 ; Schulte-Körne, Demel, Bartling & Remschmidt, 1998). In line with the phonetic model, we assume that dyslexic children are sensitive to phonetic similarity in reading, but do not use a phonological set of phoneme detectors structured by inhibitory relations based on shared phonetic properties. Therefore, dyslexic children are expected to exhibit facilitative priming and inhibitory masking effects in case of voicing similarity, whereas skilled readers exhibit inhibitory priming and facilitative masking effects. Finally, an audio-visual training about voicing was expected to reduce this difference.

In this study we chose to use a letter detection paradigm, which is a priori a purely visual and orthographic task ; however, two studies showed that this task is also sensitive to phonological information (Ziegler & Jacobs, 1995 ; Ziegler, Van Orden & Jacobs, 1997).

Experiment

Adult skilled readers, average reading third graders and dyslexic children have been tested in an experiment assessing phonetic priming and phonetic masking within one printed stimulus CVCV, an 'intra-word' priming/masking paradigm: looking at the initial consonant target position (Rank 1) allows one to investigate the masking effect that the second consonant (Rank 2) has on Rank 1; in turn, looking at Rank 2 target position allows to investigate the priming effect that Rank 1 has on Rank 2 target processing.

An additional group of dyslexic children performed the task before and after audio-visual training about voicing.

MethodParticipants

All subjects were native French speakers, had normal or corrected-to-normal vision and were right-handed. 24 University Lyon 2 students, 12 male and 12 female (mean age = 21.2 years; $SD = 1.7$ years), 12 normal reading third graders, 5 male and 7 female (mean age = 8.2 years; $SD = 0.6$ years) and 12 dyslexic children, 10 male and 2 female (mean age = 10.9 years; $SD = 1.1$ years) tested in Lyon-Sud Hospital took part in the experiment. Dyslexic children's reading age was at least 18 months behind their chronological age (Lefavrais, 1967). 50% suffered from phonological dyslexia, 42% from mixed dyslexia, and 8% from surface dyslexia. This subtyping was performed by a neuropsychologist in Lyon-Sud Hospital.

Material

The experimental list contained 96 bisyllabic CVCV pseudowords. The target letter (50% voiced consonants, 50% voiceless consonants) was the initial consonant (Rank 1) in half of them (48); it was the second consonant (Rank 2) in the other half. Voicing similarity between consonants was manipulated: 12 Rank 1 voiced targets preceded a voiced consonant (e.g., *duba*), 12 Rank 1 voiced targets preceded a voiceless one (e.g., *dupa*), 12 Rank 1 voiceless targets preceded a voiceless one (e.g., *topi*) and 12 Rank 1 voiceless targets preceded a voiced one (e.g., *tobi*). Similarly, 12 Rank 2 voiced targets followed a voiced one (e.g., *buda*), 12 Rank 2 voiced targets followed a voiceless one (e.g., *puda*), 12 Rank 2 voiceless targets followed a voiceless one (e.g., *puto*) and 12 Rank 2 voiceless targets followed a voiced one (e.g., *buto*). Voiced consonants (/d/, /b/, /g/, /v/, /z/, /Z/) and voiceless consonants (/t/, /p/, /k/, /f/, /s/, /S/) were equally presented in each rank. Additionally, 96 fillers were used for negative responses. To discourage strategies, they contained some letters used as targets in experimental stimuli, whereas the target was another letter. The list was divided into 6 blocks, their order varied across subjects with Latin-square.

Procedure

Each participant was tested individually and sat in front of a Macintosh iBook, at a distance of 57 cm from the screen. Each trial began with a 1500 ms-centered fixation dot (+), replaced immediately with a lower-cased pseudoword covering 2.2° of visual angle for 50 ms (for adults) and 85 ms (for children), followed by a 16 ms-visual mask (XXXXXX). Then, an upper-cased target letter was presented 1.2° below the previous stimuli, until the subject pressed one of the response keys to indicate if the target was present in the pseudoword, as fast and accurately as possible.

Results and discussion

A three within-subject factors (Rank : 1, 2 ; Similarity : similar, different ; Voicing : voiceless, voiced) repeated measures ANOVA was conducted on mean response times (RTs) and on error rates (ERs) for each group. Data are summarized in Table 1.

In adults, we noticed a Rank X Similarity interaction for RTs, $F_1(1,23)=4.77$, $p=.039$, $F_2(1,22)=11.27$, $p=.0028$. Voicing similarity increased RTs for Rank 2 targets, $F_1(1,23)=3.09$, $p=.09$, $F_2(1,22)=9.21$, $p=.006$, while tending to produce faster responses for Rank 1 targets and significantly reduced ERs, $F_1(1,23)=4.40$, $p=.047$, $F_2(1,22)=6.56$, $p=.018$. This pattern of results replicated phonetic priming and masking effects previously recorded with sequentially presented stimuli : in case of voicing similarity, performances for Rank 1 targets were improved, whereas performances for Rank 2 targets were decreased. This suggests that early stages of print processing involve a phonological code, that is fine enough to be described in terms of phonetic properties (Bedoin, 1998; Lukatela et al., 2000).

In third graders, Rang X Similarity interaction was significant on ERs, $F_1(1,11)=14.02$, $p=.003$, $F_2(1,22)=15.14$, $p=.001$, and on RTs, $F_1(1,11)=4.40$, $p=.059$, $F_2(1,22)=4.61$, $p=.043$. Like in adults, performances for Rank 2 targets were decreased by voicing similarity, with longer RTs, $F_1(1,11)=8.78$, $p=.013$, $F_2(1,22)=7.71$, $p=.011$, and a tendency towards more errors, $F_1(1,11)=3.44$, $p=.09$, $F_2(1,22)=4.01$, $p=.058$. Additionally, Rank 1 targets were detected more accurately in case of voicing similarity, $F_1(1,11)=11.84$, $p=.006$, $F_2(1,22)=12.26$, $p=.002$, as it was the case in adults. Therefore, children as young as third graders are sensitive to voicing similarity between consonants within a printed stimulus, in the same way as adult skilled readers. Such effects in beginning readers were a prerequisite to investigate possible impairment voicing sensitivity for dyslexic children.

Table 1 : Mean Response Time (RT) in Milliseconds and Percentage of Errors with Standard Errors (SE) in Adults, in Third Graders and in Dyslexic Children

Group		Consonant detection task in CVCV			
		RT	SE	% Error	SE
Adult Skilled Readers	Detection of Rank 1 consonant				
	Voicing similarity	707.49	22.62	8.51	1.80
	Voicing difference	732.76	26.26	13.02	2.26
	Detection of Rank 2 consonant				
	Voicing similarity	882.75	40.65	29.86	2.77
	Voicing difference	849.30	30.60	33.33	3.26
Third Grade Normal Readers	Detection of Rank 1 consonant				
	Voicing similarity	1596.31	88.59	21.15	3.34
	Voicing difference	1556.26	70.30	29.49	4.01
	Detection of Rank 2 consonant				
	Voicing similarity	2325.07	236.68	50.96	4.90
	Voicing difference	1940.43	116.69	46.80	4.87
Dyslexic Children	Detection of Rank 1 consonant				
	Voicing similarity	1425.58	93.74	23.26	3.89
	Voicing difference	1371.39	69.94	24.65	3.23
	Detection of Rank 2 consonant				
	Voicing similarity	1578.66	91.43	44.10	3.70
	Voicing difference	1775.99	108.23	42.36	3.88

In dyslexic children, there was no effect of voicing similarity on error rates, but Rank X Similarity interaction was significant on RTs, $F_1(1,11)=4.58$, $p=.055$, $F_2(1,22)=8.15$, $p=.009$.

The pattern of results differed from data obtained in adults and third graders, since RTs for Rank 2 targets were faster in case of voicing similarity for dyslexic children, $F_1(1,11)=5.64$, $p=.037$, $F_2(1,22)=8.68$, $p=.008$, whereas skilled readers' latencies for Rank 2 targets were increased by voicing similarity.

Additionally, dyslexic children did not benefit from voicing similarity for Rank 1 target detection, contrary to adults and third graders with normal reading level. Therefore, dyslexic children exhibit sensitivity to voicing similarity in reading, but their data cannot be explained by the involvement of phoneme detectors organised by lateral inhibition based on shared phonetic properties. According to the phonetic model, dyslexic children are impaired in the selection of acoustic properties to process phonemic categories (Godfrey et al., 1981; Serniclaes et al., 2001). In line with this assumption, but transposed in reading situations, data recorded in dyslexic children may reveal impairments in linking a level of knowledge about phonetic properties and a phonological level involving phoneme detectors. Therefore, phonological deficits in dyslexic children may be partly due to impairments in the phonetic organisation of phoneme detectors.

This phonological/linguistic impairment about voicing may find a solution in an audio-visual training requiring subjects to process this phonetic feature both in hearing and reading.

Audio-visual training

In a pilot investigation, we assessed the impact of an audio-visual training about voicing on performances of dyslexic children in our letter detection task.

Participants

14 dyslexic children, 9 male and 5 female, 11 were right-handed and 3 were left-handed (*mean age* = 9.8 years, *SD* = 1.1). All were native French speakers and had normal or corrected-to-normal vision, with reading age at least 18 months behind chronological age. In this pilot investigation, the control group was matched to the training group on both reading level (Lefavrais, 1967) and chronological age.

Training

This exercise is part of the programme elaborated by Danon-Boileau and Barbier (2000). In each trial, the participant listened to a CV syllable (e.g., /pa/) and decided between two printed alternatives (e.g., *pa* and *ba*) differing by voicing. Immediately after listening to the syllable, a basket-ball was falling from the top of the screen and the child pressed one of two keys to put the ball in the basket corresponding to *pa* or *ba*. Each session lasted 30 minutes.

Procedure

Each child performed the letter detection task twice (Tests 1 and 2). Between tests, the audio-visual training was achieved for 5 weeks, 4 days a week, by 6 children (trained group), whereas vocabulary drills were performed by 8 children (control group).

Results and discussion

Given the number of participants, Wilcoxon and Mann-Whitney tests have been performed on ERs. RTs were not analysed, because some conditions were associated with no accurate response, resulting in a lack of data in some subjects. Data are presented in Table 2.

In Test 1, performances did not differ between groups, $z=-.13$, $p=.90$ and no significant effect of voicing similarity can be noticed, except a tendency towards improved performances with voicing similarity in Rank 2 targets, as it was also the case in the

other group of dyslexic children in the previous experiment (Table 1). In Test 2, the pattern of results differed between groups : ERs were not affected by voicing similarity in the control group, whereas the pattern of results of trained children was quite similar to skilled readers data in Test 2. As expected, voicing similarity may probably decrease performances for Rank 2 target detection, whereas it may improve performances for Rank 1 targets, but these differences are not significant.

Table 2 : Percentage of Errors with Standard Errors (SE) in Dyslexic Children, in Test 1 and Test 2, with Audio-Visual Training About Voicing (Trained Group) or not (Control Group)

		Consonant detection task in CVCV			
		Test 1		Test 2	
Group		% Error	SE	% Error	SE
Trained	Detection of Rank 1 consonant				
Dyslexic	Voicing similarity	38.19	25.17	23.60	16.26
Children	Voicing difference	43.06	26.97	29.86	14.62
	Detection of Rank 2 consonant				
	Voicing similarity	43.75	26.6	42.36	14.62
	Voicing difference	48.61	21.47	35.42	19.58
Control	Detection of Rank 1 consonant				
Group	Voicing similarity	40.62	26.98	33.33	13.18
	Voicing difference	42.71	26.01	34.38	18.61
	Detection of Rank 2 consonant				
	Voicing similarity	51.04	21.83	39.58	25.77
	Voicing difference	56.77	24.33	37.5	23.39

Modifications observed after audio-visual training may be interpreted with caution, given the small size of the dyslexic sample undergoing training. However, the pattern of results suggests that, after training, voicing similarity is probably not processed the same way as before. Indeed, the new pattern of data is quite similar to data that have been interpreted as a result of phonetic organisation of phoneme detectors in skilled readers. Nevertheless, accounted the small size of the dyslexic sample, these results require to be replicated to allow definite conclusions.

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ABSTRACTS

Previous studies have shown that adult skilled readers are sensitive to voicing similarity of printed prime-target or target-mask pairs (Bedoin, 1998). In the present consonant detection task, phonetic priming and masking effects were assessed within one briefly presented CVCV printed stimulus. The consonant target (Rank 1 or 2) was either similar or different in voicing to the other consonant. In adult skilled readers and third graders with average reading level, voicing similarity impaired Rank 2 consonant detection and improved Rank 1 consonant detection, replicating effects found with stimuli pairs in previous experiments. These results argue for the involvement of phoneme detectors organised by inhibitory relations based on shared phonetic properties. In dyslexic children, voicing similarity improved Rank 2 target detection, suggesting impaired phonetic organisation of phoneme detectors. After audio-visual training about voicing, this pattern of results was modified in dyslexic children, and became quite similar to skilled readers' data.

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Keywords: reading, phonetics, dyslexic children, training, voicing

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