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Do consonant sonority and status influence syllable-based segmentation strategies in a visual letter detection task? Developmental evidence in French children

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Abstract

This article queries whether consonant sonority (sonorant vs. obstruent) and status (coda vs. onset) within intervocalic clusters influence syllable-based segmentation strategies. We used a modified version of the illusory conjunction paradigm to test whether French beginning, intermediate, and advanced readers were sensitive to an optimal “sonorant coda–obstruent onset” sonority profile within the syllable boundaries as a cue for a syllable-based segmentation. Data showed that children used a syllable-based segmentation that improved with reading skills and age. The results are discussed to support that the visual letter detection within pseudowords primarily and early relies on acoustic-phonetic cues within the syllable boundaries, whereas the syllable effect seems to be developmentally constrained by reading skills and age.

Introduction

In French, syllable-sized units have been proposed as relevant ortho-phonological units during reading acquisition (e.g., Chetail & Mathey, 2009; Maïonchi-Pino, Magnan, & Écalte, 2010b). Many studies have demonstrated that beginning readers rely on the phonological, orthographic, and statistical properties of syllables to process printed words (e.g., Chetail & Mathey, 2009; Colé, Magnan, & Grainger, 1999; Maïonchi-Pino et al., 2010a, 2010b). However, the acoustic-phonetic properties of phonemes within syllabic boundaries have received little attention. This study used a modified version of the illusory conjunction paradigm to address the unresolved question of whether consonant sonority (obstruent vs. sonorant) and status (coda vs. onset) within intervocalic clusters influences syllable-based segmentation strategies in French children in a silent letter detection task within pseudowords.

The illusory conjunction paradigm has been used to test the hypothesis that syllables are automatically activated for early visual word identification (e.g., in English; Prinzmetal, Hoffman, & Vest, 1991; Prinzmetal, Treiman, & Rho, 1986; in French; Doignon & Zagar, 2005, 2006). An illusory conjunction is the misperception of a briefly presented target-letter within two-colored printed items. Participants are instructed to report the color of the target-letter in the two-colored items. Two illusory conjunctions are distinguished: Illusory conjunctions that preserve the syllable boundaries (i.e., report that a target-letter ‘V’ is the same color as ‘il’ in ‘AN.Vil’, in which upper- and lowercase letters represent the two different colors, whereas the dot represents the syllable boundary) and illusory conjunctions that violate the syllable boundaries (i.e., report that a target-letter ‘v’ is the same color as ‘AN’ in ‘AN.vil’). Hence, if participants really perceive syllable-like units in the printed items, preservation illusory conjunctions would be higher than violation illusory conjunctions.

For instance, Prinzmetal and colleagues (Prinzmetal et al., 1991; Prinzmetal et al., 1986) showed that English-speaking adults and children made more preservation illusory conjunctions than violation illusory conjunctions with VC.CVC items (i.e., ‘V’ refers to ‘vowel’ and ‘C’ refers to ‘consonant’; e.g., ‘AN.VIL’). No difference was shown between preservation and violation illusory conjunctions with CV.CVC items (e.g., ‘LA.PEL’). This last-mentioned finding suggested that perceptual units are orthographically, not phonologically, defined syllable-like units. The authors argued that illegal letter sequences in the word-initial position of English words (e.g., ‘NV’ in ‘AN.VIL’) are orthographically marked syllable boundaries. However, legal letter sequences in the word-initial position do not provide orthographic information, but rather phonological information (e.g., ‘AP’ in ‘LA.PEL’; for evidence suggesting that visual word identification in French relied on a coactivation of orthographic and phonological information, see Doignon & Zagar, 2006; Doignon-Camus, Zagar, & Mathey, 2009).

Of interest, studies focused on statistical properties within syllable boundaries but disregarded intrinsic phoneme properties (e.g., *bigram trough hypothesis*; Doignon & Zagar, 2005; Seidenberg, 1987). Using a modified illusory conjunction paradigm, Fabre and Bedoin (2003) tested whether the phonetic properties of consonants (i.e., sonority) within the syllabic boundary influenced segmentation strategies of CVC.CV disyllabic pseudowords in French adults, as well as dyslexic and normally reading children. The sonority (e.g., Selkirk, 1984) describes an acoustic-phonetic aspect that refers to a sonority hierarchy between phonemes that are ranked from high-sonority (vowels) to low-sonority phonemes (i.e., ranked from liquids and nasals [classified as *sonorant*] to fricatives and stops [classified as *obstruent*]). Results did not exhibit a syllable-based segmentation in normally reading and dyslexic children; preservation illusory conjunctions were not significantly higher than violation illusory conjunctions. Furthermore, Fabre and Bedoin did not evidence any sonority effect on preservation and violation illusory conjunctions. However, adults and dyslexic children were sensitive to the optimal internal organization within syllable boundaries (i.e., ‘sonorant coda–obstruent onset’). This conforms with the *sonority sequencing principle* (Clements, 1990) which accounted for syllables that tend to respect a specific contour described with an onset maximally growing in sonority towards the vowel and falling minimally to the coda. This is also in accordance with the *syllable contact law* supporting that the optimal contact between syllables has to embed a first syllable high-sonority coda and a second syllable low-sonority onset (Murray & Vennemann, 1983). Dyslexic children reported the color of the target-letter better when the color matched the syllable boundary (color-syllable compatibility) with a high-sonority coda (sonorant; e.g., ‘VUL.ti’) than with a low-sonority coda (obstruent; e.g., ‘VUC.ti’). Further, dyslexic children correctly reported the color of the target-letter of low-sonority codas in the color-syllable incompatibility (e.g., reported that the target-letter ‘c’ was the same color as ‘ti’ in

‘VUc.ti’), which is inconsistent with phonotactic legality since ‘CT’ is a disallowed cluster in the word-initial position in French. Indeed, with a phonotactically illegal intervocalic cluster in the word-initial position (e.g., ‘rt’ in ‘cartable’; ‘schoolbag’), the syllable boundary has to fall within the intervocalic cluster (‘car.table’). Fabre and Bedoin concluded that, surprisingly, French dyslexic children are sensitive to optimal acoustic-phonetic characteristics that respect the phonotactic legality, but this sensitivity is too strict to even transgress the phonotactic legality to privilege an optimum coda over an optimum onset.

The present single experiment assesses whether consonant sonority (obstruent vs. sonorant) and status (coda vs. onset) within intervocalic clusters influences syllable-based segmentation strategies in French beginning (first grade), intermediate (third grade), and advanced readers (fifth/sixth grade). Of interest is providing further information about the factors that contribute to the developmental course of segmentation strategies in reading. We therefore aimed to determine whether typically developed implicit knowledge about syllables (e.g., Goslin & Floccia, 2007) and acoustic-phonetic components within syllables boundaries from early exposures to oral language influence an early use of syllable-based segmentation in silent reading (e.g., Doignon & Zagar, 2006; Maïonchi-Pino et al., 2010b). If so, first we should expect that preservation illusory conjunctions would be higher than violation illusory conjunctions. Preservation illusory conjunctions should then progressively increase with reading skills and age as violation illusory conjunctions decrease. However, the optimal ‘sonorant coda – obstruent onset’ sonority profile (SP) would decrease violation illusory conjunctions but increase preservation illusory conjunctions.

Based on the Fabre and Bedoin (2003) method, we also addressed three main issues as research questions. First, the two-colored printed pseudowords were displayed for 66 ms (ranged from 218 to 307 ms in Doignon & Zagar, 2006; fixed at 283 ms in Prinzmetal et al., 1991). We hypothesized that a short duration potentially prevented clear-cut sonority-modulated effects on segmentation strategies in children. Hence, we compromised and used longer fixed 230-ms display duration. Second, we pointed out that the onset of the second syllable was systematically a low-sonority consonant, whereas the target-letter was systematically the coda of the first syllable. We therefore included additional SPs to propose all possible combinations and target-letters that were either the coda or the onset. Finally, we noticed that only beginning readers were tested. The authors interpreted that reading level-matched children “were probably not trained enough in reading to understand the importance of phonotactic rules in organizing the string of letters” (Fabre & Bedoin, 2003, p. 5). Thus, we included intermediate and advanced readers who should have a higher reading level.

Method

Participants

We individually tested 84 children and labeled them from their scores in a French standardized word reading test (TIMÉ 2 [Écalle, 2003], with 28 beginning and intermediate children from first and third grade, respectively, and TIMÉ 3 [Écalle, 2006], with 28 advanced children from fifth/sixth grade). Student *t* tests showed that chronological age and reading level significantly differed between beginning and intermediate readers, $t(54) = -13.43, p < .0001$; $t(54) = -10.13, p < .0001$ and advanced readers, $t(54) = -18.40, p < .0001$; $t(54) = -22.32, p < .0001$, and between intermediate and advanced readers, $t(54) = -11.42, p < .0001$; $t(54) = -14.87, p < .0001$. All the children were French native speakers, were right-handed, and were taught reading with a mixture of analytical grapheme-to-phoneme correspondences and global procedures. They all had normal or corrected-to-normal vision. Profiles are summarized in Table 1.

Table 1

Profiles of the children with mean age (year; month), standard deviation (in parentheses), and sex ratio (boy/girl)

Group	Beginning readers		Intermediate readers		Advanced readers	
	Chronological age	Reading level	Chronological age	Reading level	Chronological age	Reading level
<i>M age</i>	7;4 (3)	7;4 (7)	8;7 (5)	8;10 (7)	11;0 (12)	11;11 (13)
<i>Sex ratio</i>	13/15		17/11		16/12	

Material and design

Experimental stimuli consisted of 24 seven-letter disyllabic pseudowords (see the Appendix). All of the letters within the pseudowords had regular grapheme-to-phoneme correspondences. Pseudowords had an initial CVC syllable structure and intervocalic cluster. Syllable boundaries were located within the intervocalic cluster. All the intervocalic clusters were considered phonotactically illegal in the word-initial position in French as in English (e.g., Hallé, Seguí, Frauenfelder, & Meunier 1998).

Consonant Sonority (sonorant vs. obstruent) within the intervocalic cluster was manipulated. A 2×2 (Coda Sonority \times Onset Sonority) design provided four SPs for intervocalic clusters: ‘sonorant–sonorant’ (e.g., ‘TOR.LADE’); ‘sonorant–obstruent’ (e.g., ‘TOL.PUDE’); ‘obstruent–sonorant’ (e.g., ‘DOT.LIRE’); ‘obstruent–obstruent’ (e.g., ‘BIC.TADE’).

The mean positional bigram frequencies¹ were calculated with a sublexical database (i.e., Surface) computed from Lexique 2 database (New, Pallier, Brysbaert, & Ferrand, 2004). The frequencies for the bigrams that precede, straddle, and follow the syllable boundary were 2,536, 273 and 1,947. High-frequency intervocalic clusters were found within the ‘obstruent – obstruent’ SP ($M = 538$; e.g., ‘CT’ (840)) and the ‘sonorant – sonorant’ SP ($M = 477$; e.g., ‘RL’ (954)). Mid-frequency ones were found within the ‘sonorant – obstruent’ SP ($M = 75$; e.g., ‘LD’ (103)) and low-frequency ones were found within the ‘obstruent – sonorant’ SP ($M = 3$; e.g., ‘TL’ (6)). Mean initial frequencies (see Footnote 1) were estimated with the French sublexical *Manulex-infra* database (Peereman, Lété, & Sprenger-Charolles, 2007) that provides sublexical frequencies in the initial position in words for French first-to-fifth grade readers. Initial frequencies for bigrams, trigrams, and syllables were 4,408, 48, 446 (CV), and 22 (CVC).

Two colors (‘red’ and ‘blue’) were assigned to the first and second syllables. The first and second syllables never had the same color. In the *color-syllable compatibility* condition, color segmentation matched the syllable-based segmentation (e.g., ‘TOL.pude’), whereas in the *color-syllable incompatibility* condition, pseudowords were segmented either before (e.g., ‘TOL.pude’) or after (e.g., ‘TOL.Pude’) the intervocalic cluster. The target-letters that subjects were to detect were either the coda or the onset within the intervocalic cluster and were always at the border of the colored segments to prevent lateral masking (e.g., ‘l’ with ‘TOL.pude’ or ‘P’ with ‘TOL.Pude’). Each pseudoword was repeated four times: Twice (coda vs. onset detection) for the color-syllable compatibility and twice (coda vs. onset detection) for the color-syllable incompatibility conditions. Both conditions were counterbalanced.

In the color-syllable compatibility condition (henceforth violation illusory conjunctions), we had violation illusory conjunctions when ‘p’ or ‘L’ in ‘TOL.pude’ was misperceived as the same color as ‘TOL’ or ‘pude’ respectively. There was no possible preservation illusory conjunction. In the color-syllable incompatibility condition (henceforth preservation illusory conjunctions), we had preservation illusory conjunctions when ‘P’ in ‘TOL.Pude’ was misperceived as the same color as ‘ude’ or when ‘l’ in ‘TOL.pude’ was misperceived as the same color as ‘TO’. There was no possible violation illusory conjunction.

Procedure

Children were individually tested in a 15-min session. The task was run with PsyScope 1.2.5 software (Cohen, McWhinney, Flatt, & Provost, 1993) on a PowerBook G4 laptop with a 60-Hz refresh rate. Two-colored pseudowords and black-colored target-letters were typed in ‘Arial’ on a white background. Target-letters and pseudowords were systematically displayed in uppercase letters. Pseudowords covered roughly 2.94° of visual angle. Trials progressed as follow: A green screen-centered square was displayed for 1500 ms then replaced by a fixation cross (‘+’) for 300 ms. As soon as the fixation cross

¹ Occurrences per million were used.

disappeared, a black-colored target-letter that corresponded to either the coda or the onset within the intervocalic cluster appeared for 1,500 ms. Then, a two-colored pseudoword flashed during 230 ms at one of the four corners of the screen, immediately followed by a 200-ms blank screen that preceded a screen-centered question mark (“?”) which remained until the child responded. A 1,000-ms-delay separated two consecutive trials. Children had to report the color of the target-letter in the flashed pseudoword. Children were instructed to respond as quickly and accurately as possible. Children were first trained with a practice list with corrective feedback. No feedback was given for the experimental trials. Trials were randomized. The software automatically recorded errors.

Results

Analyses of variance (ANOVAs) were run by subject ($F1$) and by item ($F2$) on errors ($\approx 22.5\%$ of the data). A $3 \times 2 \times 2 \times 2 \times 2$ mixed-design repeated measures ANOVA was run on error rate with Group (beginning, intermediate and advanced) as between-subjects factor and Coda Sonority (sonorant vs. obstruent), Onset Sonority (sonorant vs. obstruent), Target-letter (coda vs. onset) and Condition (violation illusory conjunctions vs. preservation illusory conjunctions) as within-subject factors. Descriptive data are summarized in Table 2.

Table 2

Descriptive data for the Coda Sonority (sonorant; obstruent), Onset Sonority (sonorant; obstruent), Target-letter (coda; onset), Group (beginning, intermediate, and advanced readers) as a function of the Condition (violation illusory conjunctions, upper panel; preservation illusory conjunctions, lower panel) with mean error (percentage; %) and standard deviation (in parentheses)

compatibility condition (violation illusory conjunctions)									
sonorant coda					obstruent coda				
sonorant onset		obstruent onset			sonorant onset		obstruent onset		
coda	onset	coda	onset	coda	onset	coda	onset	coda	onset
									Marginal Mean
Beginning									
<i>M</i>	34.5	36.3	23.8	22.6	33.9	39.9	41.7	32.1	33.1
<i>SD</i>	21.2	24.9	21.5	21.9	21.5	23.3	23.8	25.2	22.9
Intermediate									
<i>M</i>	17.3	17.3	8.3	12.5	19.6	17.9	25.0	8.9	15.9
<i>SD</i>	16.7	15.4	17.3	18.5	19.8	15.7	22.5	12.4	17.3
Advanced									
<i>M</i>	13.1	13.1	8.9	6.0	11.9	13.7	16.1	8.3	11.4
<i>SD</i>	16.6	14.6	14.0	11.3	13.5	16.4	16.7	14.0	14.6
incompatibility condition (preservation illusory conjunctions)									
sonorant coda					obstruent coda				
sonorant onset		obstruent onset			sonorant onset		obstruent onset		
coda	onset	coda	onset	coda	onset	coda	onset	coda	onset
									Marginal Mean
Beginning									
<i>M</i>	18.5	19.1	19.1	18.5	8.9	15.5	18.5	17.3	16.9
<i>SD</i>	20.0	18.6	16.2	18.3	14.0	18.1	17.2	18.4	17.6
Intermediate									
<i>M</i>	7.1	31.6	29.2	28.6	24.4	26.2	9.5	20.8	22.2
<i>SD</i>	11.5	25.0	23.4	19.2	19.5	25.4	11.5	20.6	19.5
Advanced									
<i>M</i>	35.7	39.3	44.6	42.3	36.3	35.7	24.4	23.8	35.3
<i>SD</i>	24.3	16.5	21.8	23.3	24.0	15.5	22.0	18.4	20.7

Performance varied with the Group, $F1(2, 81) = 4.86, p < .01, \eta^2_p = 0.11, F2(2, 160) = 47.56, p < .0001, \eta^2_p = 0.44$. Fisher's Least Significant Difference (LSD) post hoc tests (Bonferroni's adjusted α -level for significance, $p < .0167$) showed that beginning readers ($M = 25.0, SD = 5.6$) made more illusory conjunctions than intermediate readers ($M = 19.0, SD = 5.6$), $p < .004$. Overall, advanced readers ($M = 23.3, SD = 5.6$) did not significantly differ from beginning readers ($p < .401$) and intermediate readers ($p < .033$). The main effect of Condition was significant, $F1(1, 81) = 11.24, p < .001, \eta^2_p = 0.12; F2(1, 80) = 8.50, p < .01, \eta^2_p = 0.07$; children made more preservation illusory conjunctions ($M = 24.8, SD = 12.3$) than violation illusory conjunctions ($M = 20.1, SD = 11.7$). Other main effects were not statistically significant.

ANOVAs also showed that the Group \times Condition interaction was significant (see Table 2), $F1(2, 81) = 69.64, p < .0001, \eta^2_p = 0.63, F2 < 1$. Fisher's LSD post hoc tests (Bonferroni's adjusted α -level for significance, $p < .0033$) showed that violation illusory conjunctions were significantly higher than preservation illusory conjunctions in beginning readers ($p < .0001$), whereas preservation illusory conjunctions were higher than illusory conjunctions in intermediate ($p < .004$), and advanced readers ($p < .0001$). Then, violation illusory conjunctions were significantly higher in beginning readers than in advanced readers, ($p < .0001$). Difference is marginally significant between intermediate and

advanced readers, ($p < .09$). Preservation illusory conjunctions significantly were significantly higher in advanced readers than in beginning readers, ($p < .0001$). Difference is also significant between beginning and intermediate readers ($p < .05$).

The Condition \times Target-letter interaction was significant, $F(1, 81) = 4.61, p < .04, \eta^2_p = 0.05, F_2 < 1$. Fisher's LSD post hoc tests (Bonferroni's adjusted α -level for significance, $p < .0083$) revealed that with onsets as target-letters preservation illusory conjunctions ($M = 26.5, SD = 11.1$) were higher than violation illusory conjunctions ($M = 19.1, SD = 11.8, p < .0001$). Preservation illusory conjunctions and violation illusory conjunctions did not significantly differ with codas as target-letters ($M = 21.8, SD = 9.7; M = 22.4, SD = 9.8$ respectively; $p < .051$).

Then, the Condition \times Coda Sonority interaction was significant, $F(1, 81) = 38.22, p < .0001, \eta^2_p = 0.32, F_2(1, 80) = 6.11, p < .02, \eta^2_p = 0.06$. Tukey's Honestly Significant Difference (HSD) post hoc test (Bonferroni's adjusted α -level for significance, $p < .0083$) indicated that with sonorant codas preservation illusory conjunctions ($M = 27.8, SD = 11.2$) were higher than violation illusory conjunctions ($M = 17.8, SD = 8.6, p < .0001$). Preservation illusory conjunctions and violation illusory conjunctions did not significantly differ with obstruent codas ($M = 21.8, SD = 9.7; M = 22.4, SD = 9.8$ respectively, $p < .952$).

The Condition \times Onset Sonority interaction was also significant, $F(1, 81) = 6.96, p < .01, \eta^2_p = 0.08, F_2(1, 80) = 10.00, p < .006, \eta^2_p = 0.07$. Tukey's HSD post hoc test (Bonferroni's adjusted α -level for significance, $p < .0083$) showed that with obstruent onsets preservation illusory conjunctions ($M = 24.7, SD = 10.0$) were higher than violation illusory conjunctions ($M = 17.9, SD = 9.7; p < .0001$). Preservation illusory conjunctions and violation illusory conjunctions did not significantly differ with sonorant onsets ($M = 24.9, SD = 11.4; M = 22.4, SD = 9.7$ respectively; $p < .038$).

Finally, the Condition \times Coda Sonority \times Onset Sonority interaction was significant, $F(1, 81) = 21.06, p < .0001, \eta^2_p = 0.21, F_2(1, 80) = 13.31, p < .001, \eta^2_p = 0.09$. Tukey's HSD post hoc tests (Bonferroni's adjusted α -level for significance, $p < .002$) showed that for the 'sonorant-obstruent' SP preservation illusory conjunctions ($M = 30.4, SD = 9.1$) were higher than violation illusory conjunctions ($M = 13.7, SD = 8.5; p < .0001$). Further, preservation illusory conjunctions for the 'sonorant-obstruent' SP were higher than violation illusory conjunctions for two out of three other SPs (i.e., 'sonorant-sonorant' SP, $M = 21.9, SD = 7.8, p < .002$; 'obstruent-obstruent' SP, $M = 22.0, SD = 8.9, p < .002$; 'obstruent-sonorant' SP, $M = 22.8, SD = 8.4, p < .006$). Violation illusory conjunctions for the 'sonorant-obstruent' SP were lower than preservation illusory conjunctions for two out of three other SPs (i.e., 'sonorant-sonorant' SP, $M = 25.2, SD = 10.3, p < .0001$; 'obstruent-sonorant' SP, $M = 24.5, SD = 9.9, p < .0001$; and 'obstruent-obstruent' SP, $M = 19.1, SD = 8.7, p < .091$).

No other interaction was statistically significant or varied with the Group factor.

General discussion

This research reports a single experiment that uses a modified version of the illusory conjunction paradigm in French beginning, intermediate, and advanced readers to assess whether consonant sonority (obstruent vs. sonorant) and status (coda vs. onset) within intervocalic clusters influence syllable-based segmentation strategies in visual identification.

We obtain two results that confirm a syllable-based segmentation effect. First, we observe a preservation illusory conjunction rate (i.e., 'TOL.Pude' or 'Tol.pude' misperceived as 'TOL.pude') that is clearly overall higher than the violation illusory conjunction rate (i.e., 'TOL.pude' misperceived as 'Tol.pude' or 'TOL.Pude'). Of interest is that the error-type progressively switches to map the strengthened use of a syllable-based segmentation. Indeed, this effect depends on reading skills and age because preservation illusory conjunctions progressively increase while violation illusory conjunctions progressively decrease from beginning readers to advanced readers. Hence, at least in intermediate and advanced readers, we discard the idea that visual word identification relies on a visual serial left to right or a phonological grapheme-to-phoneme processing. Furthermore, we point out that reporting the coda color (i.e., third letter) does not differ from assigning the onset color (i.e., fourth letter) to account for a possible sequential processing.

Unsurprisingly, our results follow the developmental course initially designed by Seymour and Duncan (1997) and successively extended by Colé et al. (1999) and Maionchi-Pino et al. (2010b): Beginning readers who basically rely on a phoneme-based segmentation (i.e., grapheme-to-phoneme correspondence use) to learn how to read become able to use a syllable-based segmentation as reading

instruction increases. An insightful overview on Table 2 confirms that the syllable effect emerges progressively from beginning to advanced readers. Unlike Doignon and Zagar (2006), our results do not reveal a straightforward syllable effect in beginning readers. An available interpretation is to consider that display duration in our experiment (230 ms) was too short to allow a syllable-based segmentation. However, as previously found, the syllable effect in beginning readers might be restricted to some situations (e.g., initial high-frequency syllables, Maionchi-Pino et al., 2010b; in good readers, Colé et al., 1999). We hypothesize that the reverse effect observed from beginning to advanced readers could be dependent on the initial syllable frequency and the syllable complexity; beginning readers could be unable to fully use a syllable-based segmentation because CVC syllables are of low frequency (from 0 to 195²; $M = 21$, $SD = 45$) compared with CV syllables that are of high frequency (from 81 to 1,224 [see Footnote 2]; $M = 446$, $SD = 334$). Further, CVC syllables are generally acquired later and frequently misperceived as CV syllables (e.g., Sprenger-Charolles & Siegel, 1997), especially because CV syllables depict universally optimal phonological and acoustic-phonetic structures (e.g., Clements, 1990). Accordingly, high error rate of violation illusory conjunctions in beginning readers could ensue from a first segmentation as CV.CCVC rather than CVC.CVC.

Notably, we also confirmed another hypothesis. Children systematically exhibit sensitivity to the acoustic-phonetic properties of consonants within the syllable boundaries in French. Indeed, when children encounter the optimal ‘sonorant – obstruent’ SP (e.g. ‘LP’ in ‘TOL.PUDE’) within syllable boundaries when the syllable-based segmentation matched the color, violation illusory conjunctions drastically decreased, whereas when the syllable-based segmentation mismatched the color, preservation illusory conjunctions increased. This effect indicates that children benefit from the optimal acoustic-phonetic organization within intervocalic clusters to segment syllables, more than any other SPs, with a systematic emphasis on the obstruent onsets. This adheres with both Clements (1990), who proposed that a syllable has to conform to an onset maximally growing in sonority toward the vowel and falling minimally to the coda (e.g., ‘obstruent onset-vowel-sonorant coda’), and Murray and Vennemann (1983), who described that contact between adjacent syllables has to embed a high-sonority coda and a low-sonority onset. Further, we observe a contrasted sensitivity to consonant sonority depending on the status within the intervocalic clusters to favor a syllable-based segmentation. More specifically, there is an asymmetry between the codas and onsets for a syllable-based segmentation. Sonorant codas and obstruent onsets as target-letters induce more preservation illusory conjunctions than violation illusory conjunctions, whereas preservation illusory conjunctions and violation illusory conjunctions did not differ with obstruent codas and sonorant onsets. These results are compatible with privileged acoustic-phonetic-based assignments to a position within an intervocalic cluster. Actually, obstruent consonants prevail, and are more expected, in the onset position, whereas sonorant consonants prevail, and are more expected, in the coda position in CVC structures (e.g., 70% of sonorant codas vs. 30% of obstruent ones; Wioland, 1985).

Our statistical data³ show that the bigram trough hypothesis cannot fully account for a syllable effect; preservation illusory conjunctions were higher and violation illusory conjunctions were lower with the ‘sonorant–obstruent’ SP which bears a bigram trough as the ‘obstruent–sonorant’ SP and the ‘sonorant–sonorant’ SP which, however, do not systematically differ from the ‘obstruent–obstruent’ SP which does not bear a bigram trough. But with Manulex-infra (Peereman et al., 2007), we observe that for the ‘sonorant–sonorant’ SP (from 3,055 to 7,811; $M = 5,026$, $SD = 2,211$), all the bigrams that precede the intervocalic clusters are of high frequency. However, neither violation illusory conjunctions (21.9%) nor preservation illusory conjunctions (25.2%) systematically exhibited the highest – or the lowest – error rates. With the ‘sonorant–obstruent’ SP (from 904 to 3,691; $M = 2,479$, $SD = 1,242$), preservation illusory conjunctions (30.4%) exhibited the highest error rate while violation illusory conjunctions (13.7%) exhibited the lowest error rate. Conversely, with the ‘obstruent–obstruent’ SP (from 168 to 2,262; $M = 1,040$, $SD = 847$), preservation illusory conjunctions (19.1%) exhibited the lowest error rate while violation illusory conjunctions (22.0%) exhibited one of the lowest error rate.

² Occurrences per million were extracted from the Manulex-infra database (Peereman et al., 2007).

³ Lexique 2 (New et al., 2004) confirmed our results as follows: ‘sonorant–obstruent’ SP (e.g., ‘PIL.DORE’, ‘IL’ (3,262), ‘LD’ (103) and ‘DO’ (314)), ‘obstruent–sonorant’ SP (e.g., ‘DOT.LIRE’, ‘OT’ (2,455), ‘TL’ (6) and ‘LI’ (2,512)), ‘sonorant–sonorant’ SP (e.g., ‘PUR.LIDE’, ‘UR’ (7,811), ‘RL’ (954) and ‘LI’ (2,512)), ‘obstruent–obstruent’ SP (e.g., ‘PUC.TODE’, ‘UC’ (849), ‘CT’ (840) and ‘TO’ (1,533)).

This could argue for a combined influence of the SP and the frequency of bigrams that precede the intervocalic clusters to group the letters and favor a syllable-based segmentation.

Conclusion

Our results show, from an ongoing research, the consonant sonority's role on segmentation strategies in reading. We find, as did Fabre and Bedoin (2003), that children who have a low reading level do not exhibit a syllable effect. However, we highlight that all children have an early and long-lasting sensitivity to the acoustic-phonetic properties of phonemes within intervocalic clusters while the syllable effect seems to be developmentally constrained by reading skills followed by the sonority, especially with the optimal 'sonorant coda-obstruent onset' SP, and potentially by the syllable/bigram/trigram frequencies. This reveals that consonant sonority might be a relevant cue within the syllabic boundaries to efficiently underlie segmentation processes.

References

- Chetail, F., & Mathey, S. (2009). The syllable frequency effect in visual recognition of French words: A study in skilled and beginning readers. *Reading and Writing, 22*, 955–973.
- Clements, G. (1990). The role of the sonority cycle in core syllabification. In M. Beckman & J. Kingston (Eds.), *Papers in phonology I: Between the grammar and the physics of speech* (pp. 283–333). Cambridge, UK: Cambridge University Press.
- Cohen, J., McWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavioural Research Methods, Instruments and Computers, 25*, 257–271.
- Colé, P., Magnan, A., & Grainger, J. (1999). Syllable-sized units in visual word recognition: Evidence from skilled and beginning readers of French. *Applied Psycholinguistics, 20*, 507–532.
- Doignon, N., & Zagar, D. (2005). Illusory conjunctions in French: The nature of sublexical units in visual word recognition. *Language and Cognitive Processes, 20*, 443–464.
- Doignon, N., & Zagar, D. (2006). Les enfants en cours d'apprentissage de la lecture perçoivent-ils la syllabe à l'écrit? [Can children who are learning to read to perceive the printed syllable?]. *Canadian Journal of Experimental Psychology, 60*, 258–274.
- Doignon-Camus, N., Zagar, D., & Mathey, S. (2009). Can we see syllables in monosyllabic words? A study with illusory conjunctions. *European Journal of Cognitive Psychology, 21*, 599–614.
- Écalte, J. (2003). *Timé2: Test d'Identification de Mots Écrits pour enfants de 6 à 8 ans* [Timé 2: A visual word identification test for children from 6 to 8 years old]. Paris, France: ECPA.
- Écalte, J. (2006). *Timé3: Test d'Identification de Mots Écrits pour enfants de 7 à 15 ans*. [Timé 3: A visual word identification test for children from 7 to 15 years old]. Paris, France: Mot-à-Mot.
- Fabre, D., & Bedoin, N. (2003). Sensitivity to sonority for print processing in normal readers and dyslexic children. *Current Psychology Letters: Brain, Behaviour and Cognition, 10*, 1–8.
- Goslin, J., & Floccia, C. (2007). Comparing French syllabification in preliterate children and adults. *Applied Psycholinguistics, 28*, 341–367.
- Hallé, P., Seguí, J., Frauenfelder, U., & Meunier, C. (1998). The processing of illegal consonant clusters: A case of perceptual assimilation? *Journal of Experimental Psychology: Human Perception and Performance, 24*, 592–608.
- Maïonchi-Pino, N., Magnan, A., & Écalte, J. (2010a). The nature of the phonological processing in French dyslexic children: Evidence for the phonological syllable and linguistic features' role in silent reading and speech discrimination. *Annals of Dyslexia, 60*, 123–150.
- Maïonchi-Pino, N., Magnan, A., & Écalte, J. (2010b). Syllable frequency effects in visual word recognition: Developmental approach in French children. *Journal of Applied Developmental Psychology, 31*, 70–82.
- Murray, R., & Vennemann, T. (1983). Sound change and syllable structure in Germanic phonology. *Language, 59*, 514–528.
- New, B., Pallier, C., Brysbaert, M., & Ferrand, L. (2004). Lexique 2: A new French lexical database. *Behavior Research Methods, Instruments, & Computers, 36*, 516–524.

- Peereman, R., Lété, B., & Sprenger-Charolles, L. (2007). Manulex-Infra: Distributional characteristics of grapheme–phoneme mappings, infra-lexical and lexical units in child-directed written material. *Behavior Research Methods, Instruments, & Computers*, *39*, 579–589.
- Prinzmetal, W., Hoffman, H., & Vest, K. (1991). Automatic processes in word perception: An analysis from illusory conjunctions. *Journal of Experimental Psychology: Human Perception and Performance*, *17*, 902–923.
- Prinzmetal, W., Treiman, R., & Rho, S. (1986). How to see a reading unit. *Journal of Memory and Language*, *25*, 461–475.
- Seidenberg, M. (1987). Sublexical structures in visual word recognition: Access units or orthographic redundancy? In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 245–263). Hillsdale, NJ: Erlbaum.
- Selkirk, E. (1984). On the major class features and syllable theory. In M. Arnolf & R. Octyle (Eds.), *Language and sound structure* (pp. 107–136). Cambridge, MA: MIT Press.
- Seymour, P., & Duncan, L. (1997). Small versus large unit theories of reading acquisition. *Dyslexia*, *3*, 125–134.
- Sprenger-Charolles, L., & Siegel, L. (1997). A longitudinal study of the effects of syllabic structure on the development of reading and spelling skills in French. *Applied Psycholinguistics* *18*, 485–505.
- Wioland, F. (1985). *Les structures syllabiques du français : Fréquence et distribution des phonèmes consonantiques. Contraintes idiomatiques dans les séquences consonantiques* [Syllable structures of French. Consonant phoneme frequency and distribution. Idiomatic constraints in consonant sequences]. Paris, France: Slatkine-Champion.

Appendix*Stimuli used in the experiment*

Sonorant Coda		Obstruent Coda	
Sonorant Onset	Obstruent Onset	Sonorant Onset	Obstruent Onset
BILRATE	BULPOTE	BUDLOTE	BICTADE
BIRLOTE	PILDORE	DATLORE	BIPTADE
DALRITE	PULDITE	DOTLIRE	DACTULE
PURLIDE	TALPIDE	PIDLARE	DAPTOLE
TOLRUDE	TOLDARE	PITLUDE	DOPTILE
TORLADE	TOLPUDE	TADLITE	PUCTODE