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Allophonic Perception in Dyslexia: An Overview

Percepción alofónica en la dislexia: una revisión

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Allophonic theory claims that people affected by dyslexia perceive speech in allophonic rather than phonemic units. After a brief review of the featural theory of speech perception, the evidence supporting the allophonic theory is summarized. The difference between allophonic perception and reduced phoneme perception acuity is emphasized, the latter being a common characteristic of various disorders of language development and thus not specific to dyslexia. Taking this fundamental difference into account, the counterevidence against allophonic theory is examined, and proposals for future testing and remediation are formulated.

Keywords: Dyslexia; Allophonic Theory; Categorical Perception; Phonemic Acuity.

La teoría alofónica defiende que las personas afectadas por dislexia perciben el habla mediante unidades alofónicas en lugar de unidades fonémicas. Después de revisar brevemente la teoría de rasgos de la percepción del habla se presenta un resumen de la evidencia que apoya la teoría alofónica. Se enfatiza la diferencia entre la percepción alofónica y la reducción de la agudeza en la percepción de fonemas, siendo esta última una característica común en muchos trastornos del desarrollo del lenguaje y, por tanto, no específica de la dislexia. Teniendo en cuenta esta diferencia fundamental, se examina la evidencia contraria a la teoría alofónica y se formulan propuestas para futuras evaluaciones e intervenciones.

Palabras clave: Dislexia; Teoría Alofónica; Percepción Categorial; Agudeza Fonémica.

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In an investigation on categorical perception in dyslexic children, we found that they perceived differences between acoustic variants of the same phoneme (e.g. two different /b/) with *greater* accuracy than neurotypical children (Serniclaes, Sprenger-Charolles, Carré & Démonet, 2001). Further, it appeared that dyslexics were specifically sensitive to allophonic variants of the same phoneme, i.e. to differences between sounds that belong to different phoneme categories in other languages (Serniclaes, Van Heghe, Mousty, Carré & Sprenger-Charolles, 2004). These findings were rather unusual in light of the large repertoire of deficits associated to dyslexia. Phonemic awareness, phonological memory, attention, audition, vision..., all these capacities have been shown, more or less clearly, to be deficient in people affected by specific reading problems (for a review see: Sprenger-Charolles, Colé & Serniclaes, 2006). Instead, we found that dyslexics performed *better* than neurotypicals in the perception of allophones and that their improved performance, in spite of its potential functional advantages for learning foreign languages, constituted a specific handicap for learning to read. Perceiving allophones of the same phoneme as distinct units disturbs the alphabetic principle according to which each grapheme is ideally associated with one phoneme (as in Spanish), with correspondingly straightforward implications for the acquisition of literacy.

Here I review the evidence in support of, and counterevidence against, the allophonic theory of dyslexia. The accumulation of various findings is used to formulate a new theoretical synthesis and new perspectives for remediation. After a brief review of the featural theory of speech perception, I will summarize the evidence in favor of the allophonic theory. I will then explain the difference between allophonic perception and reduced phoneme perception acuity, the latter being a common characteristic of various disorders of language development and thus not specific to dyslexia. Taking account of this fundamental difference, I will examine the counterevidence against allophonic theory and formulate proposals for future testing and remediation.

Features and phonemes in speech perception

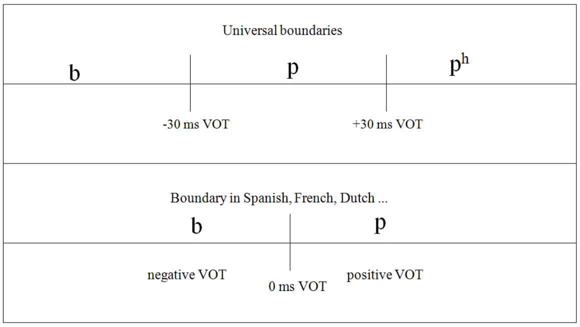
Early development of speech perception in infancy: couplings between universal psychoacoustic thresholds

The basic building blocks of phonological systems are differential units: not phonemes but oppositions between phonemes (Jakobson, 1973, p.130). A phoneme can take multiple different acoustic forms, depending on the surrounding phonemes, but the relative difference between two phonemes remains constant. For example, what distinguishes /p/ from /z/ is a set of relative properties or "features": a later onset of voice ("voicing" feature), lower formant frequencies ("place of articulation") and shorter duration ("manner of articulation"). The absolute values of voice onset time (VOT), formant frequencies and duration of both /p/ and /z/ vary with the vocalic context, but the relative differences in VOT, frequency and duration remain fairly constant and, according to the distinctive feature theory, these differences are invariant at some level of perceptual processing.

Supposing that features are indeed perceptually invariant and given that phonemes can be defined as "bundles" of features (Clements, 1985), the latter are also potentially invariant. However, features are universal, language-independent properties, whereas phonemes are specific to each language. Grouping the universal features into language-specific phonemes is a fairly complex process.

To illustrate this point, take the example of the voicing feature. Evidence from various indicates that the perception of VOT is anchored in psychoacoustic thresholds or "boundaries" (to adopt the common terminology in this field of research). Sensitivity to universal VOT boundaries, located at some -30 and +30 ms VOT, has been evidenced in behavioral studies with nonspeech analogues of VOT (Pisoni, 1977), electrophysiological studies with monkeys (Sinnott & Gillmore, 2004), evoked potentials collected using speech stimuli with human participants (Hoonhorst, Colin, Deltenre, Radeau & Serniclaes, 2009a) and experiments with pre-linguistic children (below six months of age and irrespective of linguistic background: from a Spanish background, Lasky, Syrdal-Lasky & Klein, 1975; from an English background, Aslin, Pisoni, Hennessy & Perry, 1981; from a French background, Hoonhorst, Colin, Deltenre, Radeau & Serniclaes, 2009b). Now, these ±30 ms VOT boundaries are used to separate phonemes in languages with three voicing categories (e.g. Thai: Lisker & Abramson, 1970). However, in several other languages with only two voicing categories (Spanish, French, Dutch, etc.) the phonemic boundary is located at 0 ms VOT, and appears later during perceptual development, after 6 months of age (in Spanish: Eilers, Gavin & Wilson, 1979; in French: Hoonhorst et al., 2009b). This example of voicing perception illustrates how a phonemic boundary is derived from universal boundaries. It should be stressed that the phonemic boundary, which corresponds to the perception of the temporal order of two events (0 ms is the limit between anticipation/delay), is intrinsically more complex than the universal boundaries, which correspond to the perception of either an anticipation or a delay (Figure 1). The acquisition of this phonemic boundary results from a "coupling" between psychoacoustic thresholds, i.e. from cross-dependencies in the perception of these thresholds (Serniclaes, 2011).

Figure 1. (Adapted from Serniclaes et al., 2004). Universal VOT boundaries (at -30 and +30 ms) correspond to the perception of either an anticipation or a delay. The 0 ms VOT boundary is found in some languages (including Spanish, French, and Dutch).



The couplings between universal psychoacoustic boundaries are not specific to voicing. The perception of place of articulation contrasts between stop consonants depends on the transitions of the second and third formants (F2 and F3 transitions). The place boundaries in the F2-F3 transition space are related to changes in the upward/downward direction of the F2 and F3 transitions, which constitute universal psychoacoustic boundaries (for a review see Serniclaes, 2011). These universal boundaries are combined in specific ways for perceiving place of articulation in different languages (Serniclaes & Geng, 2009).

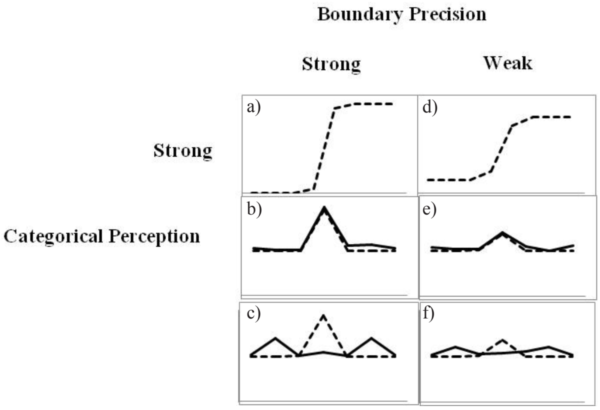
However complex they may be, the phonemic couplings between universal boundaries seem to emerge quite spontaneously after the child has been exposed to the sounds of the environmental language for several months. However, some children might not develop such phonemic couplings for genetic reasons, and these children might then enter into an "allophonic" mode of speech perception, i.e. perceiving the universal categories which are sometimes used as phonemes in other languages (e.g. the three voicing categories of Thai). Lacking phoneme representations, the children developing allophonic perception might then later present specific reading problems.

Later development of speech perception during childhood and adolescence: acquisition of secondary acoustic cues

Adults' perception of phonemic features is not only based on couplings between universal boundaries. These boundaries play a major role in the perception of a given phonemic feature, but various other acoustic cues also contribute to the perception of the same phonemic feature, with lesser perceptual weight. For example, in French the mean VOT boundary is located at 0 ms VOT, but a decrease/increase in pitch (F0) shifts this boundary toward positive/negative VOTs (Serniclaes, 1987). These changes in VOT perception parallel those observed in VOT production: VOT is longer, rendering the percept more voiceless, in contexts where F0 is lower, rendering the percept more voiced. The integration of secondary cues such as F0 in voicing perception compensates for contextual variations in VOT (due to coarticulation). These "compensations for coarticulation" (for a recent review see Mitterer, 2006) contribute to the perceptual invariance of the feature.

The integration of secondary acoustic cues into feature perception occurs later in the course of development. The emergence of phonemic couplings, before one year of age, is followed by a long-lasting evolution that only ends during adolescence. Phonemic couplings between universal features do not generate full phoneme representations comparable to those found in adults. This has been evidenced in studies on the perception of speech sounds that vary between two different phonemes along some acoustic continuum (e.g. a VOT continuum between /b/ and /p/). Compared to adults, children's identification functions exhibit floor/ceiling effects at the ends of the continuum, i.e. asymptotic values below perfect identification (see Figure 2, from Medina, Hoonhorst, Bogliotti & Serniclaes, 2010; for a review see Hoonhorst, Medina, Colin, Markessis, Radeau, Deltenre & Serniclaes, 2011). Such differences in the asymptotic values of the identification functions arise from an inappropriate perceptual weighting of secondary acoustic cues, as demonstrated by Treisman (1999). With appropriately low weightings these cues affect only the location of the phonemic boundary, somewhere in the middle of the continuum, but when overweighted they will instead generate asymptotes below/above the 100%/0% scores at the endpoints of the continuum. The overweighting of secondary acoustic cues thus has the effect of reducing the accuracy of phoneme identification.

Figure 2. (Adapted from Medina et al., 2010). Categorical properties. These properties are illustrated with hypothetical identification and discrimination curves. Boundary precision is larger when the identification slopes are steeper (compare Fig.2a with Fig.2d) or, equivalently, when the discrimination peaks are higher (Fig.2b with Fig.2e; Fig.2c with 2f). Categorical perception is greater when the observed and expected peaks are matched (compare Fig.2b with Fig.2c; Fig.2e with Fig.2f).



Children with language pathologies generally exhibit a weaker degree of accuracy in phonemic feature perception when compared to neurotypical children of the same age. This is true not only for dyslexics but also for e.g. deaf children with cochlear implants (Bouton, Serniclaes, Colé & Bertoncini, accepted ; Medina & Serniclaes, 2009). Contrary to allophonic perception, reduced perceptual accuracy is not specific to dyslexia and is a matter of developmental delay rather than deviance.

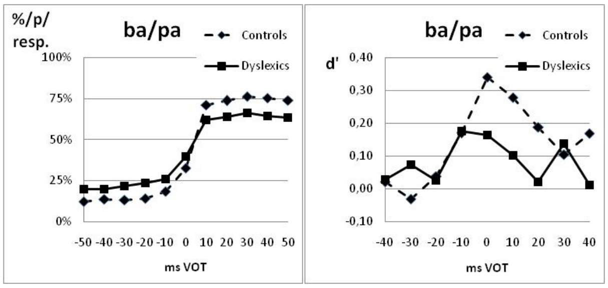
Allophonic perception

Evidence in support of allophonic perception

Dyslexic children are better at within-category phoneme perception than normal readers (Serniclaes et al., 2001) and they are more sensitive to allophonic contrasts within phonemic categories (Serniclaes et al., 2004), suggesting a specific mode of perception based on allophones rather than on phonemes. This mode of speech perception might constitute a serious obstacle for the formation of automatic grapheme–phoneme associations, necessary to establish fluent reading.

The incentive for postulating an allophonic mode of speech perception in children arose from research on Categorical Perception. Categorical Perception (CP) means that only differences between categories can be perceived, not within-category variants (Liberman, Harris, Hoffman & Griffith, 1957). Notice that speech perception is often not perfectly categorical and that the degree of CP depends on various factors (Harnad, 1988). Notably, children affected by dyslexia have been shown to suffer from a deficit in CP of speech sounds in a fairly large number of studies, beginning with Brandt and Rosen (1980). However, the theoretical importance of CP deficits only became apparent much more recently, when it was shown that dyslexics not only have weaker discrimination between categories but also *better* discrimination within categories (Serniclaes et al., 2001). Instead of being a matter of weakened resolution, as in the perceptual deficits associated with dyslexia, where sensory capacities are always assumed to be reduced, the CP deficit arises from an overdiscrimination of stimulus differences which are not functional for linguistic purposes. Such differences are 'allophonic' in nature in the sense that they correspond to distinctions which are mere contextual variants of phonemes in the language of interest, while being phonemic in other languages (Bogliotti, Serniclaes, Messaoud-Galusi & Sprenger-Charolles 2008; Burnham, 2003; Luque, Serniclaes, López-Zamora, Bordoy, Giménez, Rosales & Varona, 2011; Serniclaes et al., 2004, see Figure 3).

Figure 3. Identification (left) and discrimination (right) of VOT contrasts by Spanish dyslexic and control children (7 & 9 years old) on a ba/pa continuum. The asymptotic values of the identification function exhibit larger floor/ceiling effects for the dyslexics vs. controls, reflecting weaker perceptual accuracy. Controls display a major discrimination peak at the phonological boundary (0 ms VOT). Dyslexics display three different peaks, one at the phonological boundary and the two others at the universal boundaries (-30 and +30 ms), indicating allophonic perception.



The CP deficit thus seems to reveal an 'allophonic' mode of speech perception, characterized by the use of allophones rather than phonemes. The inflation of the phonological repertoire in dyslexics has evident implications for reading acquisition because, even in languages with a transparent reading system (e.g. Spanish), perceiving speech with allophones instead of phonemes blurs the one-to-one correspondence between letters and phonemes.

Developmental origin of allophonic perception

Because the perception of allophonic distinctions is not necessary for recognizing spoken words, the question of its origin in the course of language development naturally poses itself. As we have seen, children do not have to learn these distinctions because they correspond to universal boundaries which are already present at birth. It is only after exposure to the sounds of their native language that children acquire language-specific phonological contrasts through coupling between universal boundaries. Remember that for the voicing feature, the VOT boundary is located at 0 ms in various languages such as French, Spanish and Polish (Ganong & Keating, 1981; Medina et al., 2010; Williams, 1977): this value is not included in universal boundaries (located at ± 30 ms VOT), although it does appear fairly early in the course of language development (Eilers et al., 1979; Hoonhorst et al., 2009b). This means that a new boundary, irreducible to one of the two natural phonetic boundaries and falling right in between them, has to be acquired. The process that makes this acquisition possible is fairly complex, as it requires a coupling between two universal mechanisms.

As these couplings between predispositions are fairly complex processes, it is not surprising that they might fail in some part of the population, giving rise to allophonic rather than phonemic representations of speech sounds. This conjecture is supported by genetic studies suggesting a hereditary basis for dyslexia (for an overview: Démonet, Taylor & Chaix, 2004).

Allophonic perception probably does not in any significant way hamper spoken word recognition, though it may render it rather costly by requiring the processing of a great deal of redundant information. The impact of allophonic perception on reading acquisition is much greater. A child using allophonic rather than phonemic categories will encounter considerable difficulties establishing correspondences between phonemes and graphemes, even in a language with a perfectly transparent orthography. Indeed, even though such a language would offer one-to-one correspondences between phonemes and graphemes, a child perceiving speech in allophones would be confronted with many-to-one correspondences, as there are still several allophones for a single phoneme. Computer simulations support the hypothesis of a causal relationship between the CP deficit and dyslexia by showing that the suppression of "phonological attractions" between phonetic features, conceptually similar to the "phonological couplings" defined above, has important negative effects on the reading performance of a connectionist network (Harm & Seidenberg, 1999). This supports the argument that allophonic perception may severely affect reading performance in humans. Finally, a study with illiterate adults found that they did not present a CP deficit (Serniclaes, Ventura, Morais & Kolinsky, 2005), indicating that allophonic perception is the cause rather than the consequence of dyslexia.

Allophonic perception vs. reduced perceptual acuity

Allophonic perception is a discrepancy between identification processes based on language-specific phonological boundaries and discrimination processes based on universal psychoacoustic boundaries. Dyslexics do not only display allophonic perception; they also have reduced acuity in both the identification and discrimination of phonological features. The difference between reduced perceptual acuity and allophonic perception is that the first is a quantitative deficit, a matter of irrelevant weightings of secondary acoustic cues for a given phonological feature as suggested by Treisman (1999), whereas allophonic perception entails a qualitative deficit in the integration of the acoustic cues that play a major role in feature perception.

A deficit in perceptual acuity is reflected by a reduced discrimination peak, a shallower slope of the identification function, and also by asymptotic floor and ceiling identification scores (Figure 2). Many studies have shown that dyslexics display identification functions with a shallower slope, or equivalently a smaller discrimination peak, along some stimulus continuum, although some studies have also failed to find significant differences (for a review see: Vandermosten, Boets, Luts, Poelmans, Wouters & Ghesquière, 2011).

However, the acuity of feature perception depends not only on reading status but also on other factors such as age and auditory status. Various studies have shown that categorical precision changes as a function of age in typical children (for a review see: Hoonhorst et al., 2011). Also, deaf children with a cochlear implant display a lesser amount of categorical precision than typical hearing children with the same amount of auditory experience (Bouton et al., accepted; Medina & Serniclaes, 2009). By contrast, neither age nor auditory status has an effect on categorical perception (no effect of age: Medina et al., 2010; Hoonhorst et al., 2011; no effect of auditory status: Bouton et al., accepted; Medina & Serniclaes, 2009;). Notice, however, that an accuracy deficit has also been evidenced in dyslexic adults (Ruff, Marie, Celsis, Cardebat & Démonet, 2003; van Beinum, Schwippert, Been, van Leeuwen & Kuijpers, 2005; Vandermosten, Boets, Luts, Poelmans, Golestani, Wouters & Ghesquière, 2010), suggesting that is not only a matter of delay but also of deviance.

To summarize, there is overwhelming evidence that dyslexics display a deficit in perceptual accuracy. However, this deficit is not specific to dyslexia and is in part a matter of developmental delay. It should not be confused with allophonic perception, which is specific to dyslexia, or to children with multiple deficits including reading problems (dysphasic children: Zobouyan, Bertoncini & Serniclaes, 2010; children with William's syndrome: Majerus, Poncelet, Bérault, Audrey, Zesiger, Serniclaes & Barisnikov, 2011; high level autistic children: You, Serniclaes Rider & Chabane, 2011).

Neuronal substrate of allophonic perception

Although allophonic perception in dyslexic children has been evidenced in at least five different behavioral studies (Bogliotti et al., 2008; Burnham, 2003; Luque et al., 2011; Noordenbos, Segers, Mitterer, Serniclaes & Verhoeven, 2010; Serniclaes et al., 2004), there also negative findings. In a study on the perception of the difference between short and long positive VOT, which is phonemic in Korean but allophonic in French, Ramus and Szenkovits (2008) reported no overdiscrimination of this contrast by French dyslexic children.

However, the absence of allophonic perception in behavioral responses does not demonstrate the absence of the relevant neuronal substrate. In a follow-up study with Dutch children with a bə/də continuum, Noordenbos et al. (2010) did not find allophonic perception for children at familial risk for dyslexia, whereas the same children did exhibit allophonic perception in kindergarten. However, a further study with evoked potentials evidenced an increased Mismatch Negativity (MMN) at an allophonic boundary (Noordenbos et al., 2010). This suggests that people at familial risk for dyslexia, including those who will later develop dyslexia, process speech contrasts along allophonic neuronal pathways even when they successfully use alternative strategies for coping with the demands of behavioral tasks.

The neuronal correlates of both phonemic and allophonic perception have been evidenced in three related studies using the same stimulus material. Neuronal responses to sinewave analogues of ba/da syllables were collected with either fMRI in neurotypical adults (Dehaene-Lambertz, Pallier, Serniclaes, Sprenger-Charolles, Jobert & Dehaene, 2005) or with PET scan in both neurotypical and dyslexic adults (Dufor, Serniclaes, Sprenger-Charolles & Démonet, 2007; 2009). The advantage of sinewave analogues is that they are spontaneously perceived as nonspeech whistles by naive listeners and are perceived as speech sounds after debriefing (Remez, Rubin, Pisoni & Carrell, 1981). This makes it possible to compare behavioral and neuronal responses in two different modes, nonspeech vs. speech, with exactly the same acoustic material, thereby avoiding any acoustic confounder. The results of the two first sinewave studies are presented in Figure 4. The fMRI study (Figure 4a) showed that the change from nonspeech to speech mode generated an increase in neuronal activity to the different stimulus contrasts along the ba/da continuum. However, increased activity was larger for the contrast straddling the phonemic boundary, compared to the intra-phonemic contrast, in only one region: the left supra-marginal gyrus (SMG), a parietal region located on the motor-phonological ("dorsal") pathway of speech perception. The first PET scan study, by Démonet et al. (2004), also revealed a speech-specific increase of phonemic discrimination in the left SMG for neurotypical adults but not for dyslexics (Figure 4b). The fact that no difference was present in the nonspeech mode suggests that dyslexics do not have deficits in the perception of psychoacoustic boundaries, contrary to claims made in defenses of *auditory* theories (most recently: Vandermosten et al., 2010; 2011).

Figure 4. Differences in neural activity between nonspeech and speech mode in the supramarginal gyrus: in neurotypical adults in an fMRI study (Figure 4a, adapted from Dehaene-Lambertz et al., 2005); in dyslexic vs neurotypical adults in a PET scan study (Figure 4b, adapted from Dufor et al. 2007).

Figure 4a.

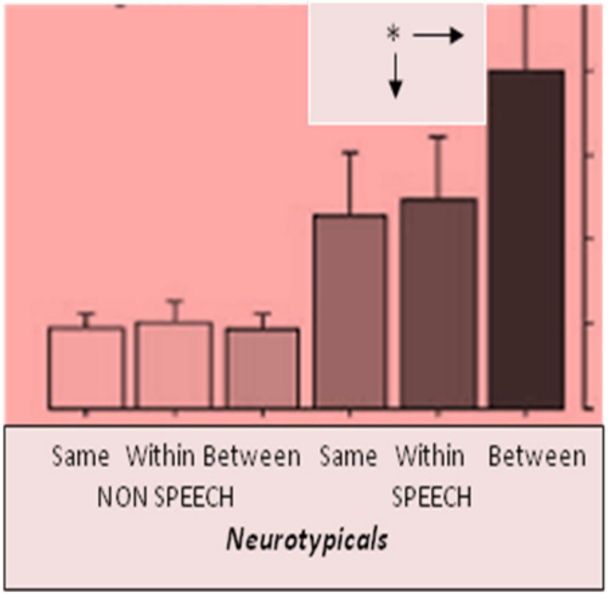
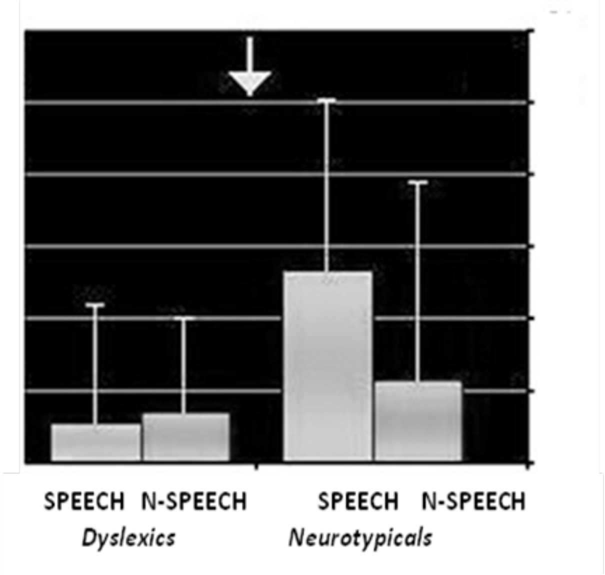
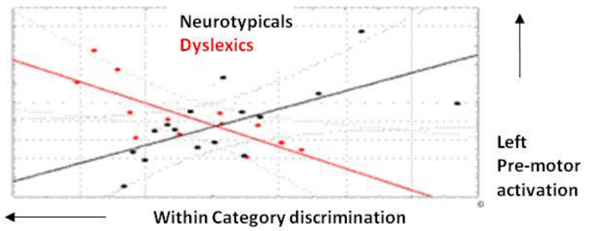


Figure 4b.



In a further examination of the PET scan data collected in the second study, Dufor et al. (2009) evidenced subtle differences between neurotypicals and dyslexics in their responses to intra-phonemic contrasts. These differences were located in a left pre-frontal region (left frontal operculum) that is close to Broca's area (Figure 5). Adult dyslexics were *more* "allophonic" (they discriminated better within category pairs) when they activated the left frontal operculum, whereas controls were *less* "allophonic" when they activated the same areas. It would thus seem that allophonic perception only prevails when speech is perceived in relationship to motor representations (along Hickok & Poeppel's 2007 "dorsal stream"), remembering that reading aloud is the "Sine qua non of reading acquisition" (Share, 1995).

Figure 5. Differences in neural activity between nonspeech and speech mode between dyslexic and neurotypical adults, mainly in the left pre-motor region (1* in the graph adapted from Dufor et al., 2009).

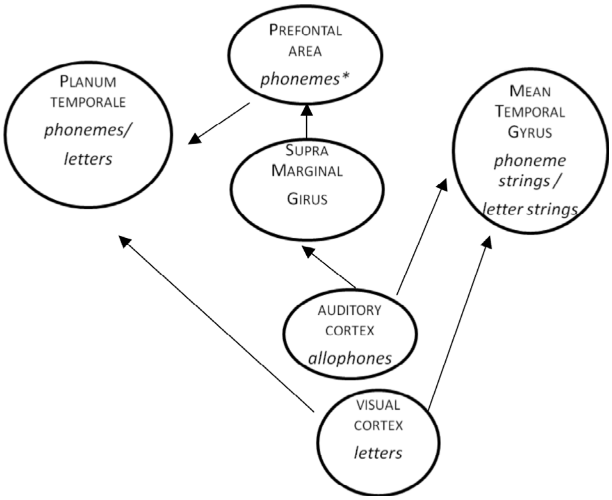


Allophonic framework

The accumulation of empirical evidence on allophonic perception, and more generally progress on the brain processes involved in reading, suggests a major modification to the allophonic model. The information-processing model that we proposed in 2004 (Serniclaes et al., Fig.1) has been modified to incorporate three major changes. A first modification is motivated by the fact that the phonetic processing level, between the acoustic and phonological levels, no longer seems necessary. As explained above, the universal allophonic features correspond to natural psychoacoustic thresholds instead of being specific to speech (Serniclaes, 2011). The phonetic processing stage is therefore no longer present in the model presented in Figure 6.

A second modification is motivated by the fact that the crucial difference in phonological representations between dyslexics and neurotypical readers, phonemic vs. allophonic, is located in the left pre-motor area (Dufor et al., 2009). Consequently, the site of the difference in phonological processing is now more specific and is located in this area. A third modification is motivated by the discovery of an integrative sound-letter area in the vicinity of the auditory cortex (anterior superior temporal gyrus, Planum Temporale/Heschl's Sulcus and Superior Temporal Sulcus: Blau et al., 2010). Accordingly, the implications of allophonic perception for reading should play out in this integrative sound-letter area. However, the mere integration of speech sounds and letters would raise problems for reading because speech sounds are categorized into allophonic, rather than phonemic, categories without transiting through the left pre-motor area. Therefore, a top-down flux from the left pre-motor area to the integrative sound-letter area has been added to the model. This top-down flux would carry phonemes for neurotypicals but untransformed allophones for dyslexics, thereby explaining their specific reading problem. Finally, with perfectly transparent orthographic systems, letters can be used as visual units in the integrative area. However, in other systems, the letters have to be recoded into graphemes in order to obtain one-to-one relationships with phonemes.

Figure 6. Allophonic framework in the brain. Dorsal pathway: In neurotypical processing, speech sounds are categorized into allophonic categories in the auditory cortex and are combined into phonemic categories in the left pre-frontal cortex (Dufor et al., 2009) after transiting through the supra-marginal gyrus (Dufor et al., 2007). During reading acquisition, phonemes are associated to letters in an auditory-visual integration area (in an area including the planum temporale: Blau, Reithler, van Atteveldt, Seitz, Gerretsen, Goebel & Blomert, 2010; Blau, van Atteveldt, Ekkebus, Goebel & Blomert, 2009). In dyslexics, the allophone-phoneme conversion is lacking and allophones are sent to the integration area instead of phonemes. Ventral pathway: letter-phoneme integration occurs in the lexical interface (in an area including the Mean Temporal Gyrus: Hickok & Poeppel, 2007). Phoneme representation is less categorical, more context-dependent, in the lexicon (McMurray, Tanenhaus & Aslin, 2002) suggesting that phonemes are chunked into strings.



Perspectives for remediation

However convincing the arguments in support of a theory of dyslexia might be, its greatest test is whether the theory can or cannot help to remediate the reading deficits of dyslexics. There have been at least six attempts to remediate dyslexia through teaching phonemic perception. Hurford (1990) claimed that discriminant training of minimal pairs of phonemes improved metaphonological capacities as assessed with a phoneme subtraction task. Veuillet, Magnan, Ecalle, Thai-Van and Collet (2007) also used discriminant training with minimal phoneme contrasts and found both behavioral (location of the VOT boundary) and neuronal improvements (asymmetric activity in the medial olivocochlear system) with implications for reading in dyslexic children after training. Van Heghe (2001) trained dyslexic children to discriminate differences between phonemes and to ignore acoustic differences within phonemic categories. Surprisingly, the training did not improve categorical perception but it did improve metaphonological capacities. However, a simple test-retest effect could not be excluded because the size of the control group was too small to allow firm conclusions. Bogliotti (2005) also trained dyslexic children to discriminate differences between phonemes but, instead of teaching the children to ignore within-category differences, she taught them to identify them with the same label (following a procedure initiated by Guenther & Bohland, 2002; Guenther, Husain, Cohen & Shinn-Cunningham, 1999). The training improved the accuracy of phoneme identification but it did not change categorical perception around the phonemic boundary. However, and again surprisingly, the training induced discrimination peaks around allophonic boundaries (Bogliotti & Serniclaes, 2011). Collet, Serniclaes, Colin and Leybaert (2011) trained dysphasic children with a discrimination task based on a perceptual fading paradigm, which consists in progressively reducing the size of the acoustic difference between two stimuli that straddle the phonemic boundary (Jamieson & Morosan, 1986). The results showed a transitory emergence of discrimination peaks on the allophonic VOT boundaries (-30 and +30 ms) followed by an improvement of categorical perception around the phonemic VOT boundary (0 ms in French, as in Spanish). What is more, the training improved phonemic awareness, suggesting possible implications for reading performance. Finally, Chobert (2011) showed that: 1) dyslexic children displayed similar MMN peaks for between- and within-category VOT differences, indicating allophonic perception, contrary to neurotypical children who displayed a larger MMN for between- vs. within-category VOT differences; 2) musical training improved phonemic MMN in dyslexic children, although this improvement did not generalize to phonemic awareness.

Overall these different attempts to remediate reading performance point to a possible solution with a well-devised method for improving categorical perception. At least three factors are in play for this purpose: the choice of sound contrast, which has to be complex enough to elicit phonemic couplings, the form of discrimination training, which should proceed through increasing levels of complexity, and what might be termed a “lateral approach” to improving speech perception by transferring skills from another cognitive domain.

Conclusions

In a nutshell: (1) there is a fairly large amount of behavioral and neuronal evidence to show that dyslexic children perceive allophonic speech contrasts better than neurotypical children; (2) the neural site of allophonic perception is close to Broca’s area; (3) allophonic perception can be still present in neuronal data even when behaviorally absent; (4) remediation of allophonic perception is possible and there are hints to suggest that this might help to remediate dyslexia.

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