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# Phonological processing deficits as a universal model for dyslexia: evidence from different orthographies

## *Déficit em processamento fonológico como um modelo universal para a dislexia: evidência a partir de diferentes ortografias*

### ABSTRACT

**Purpose:** To verify the universal nature of the phonological processing deficit hypothesis for dyslexia, since the most influential studies on the topic were conducted in children or adults speakers of English. **Research strategy:** A systematic review was designed, conducted and analyzed using PubMed, Science Direct, and SciELO databases. **Selection criteria:** The literature search was conducted using the terms “phonological processing” AND “dyslexia” in publications of the last ten years (2004–2014). **Data analysis:** Following screening of (a) titles and abstracts and (b) full papers, 187 articles were identified as meeting the pre-established inclusion criteria. **Results:** The phonological processing deficit hypothesis was explored in studies involving several languages. More importantly, we identify studies in all types of writing systems such as ideographic, syllabic and logographic, as well as alphabetic orthography, with different levels of orthography-phonology consistency. **Conclusion:** The phonological processing hypothesis was considered as a valid explanation to dyslexia, in a wide variety of spoken languages and writing systems.

### RESUMO

**Objetivo:** Verificar a natureza universal da hipótese do déficit de processamento fonológico para a dislexia, uma vez que os estudos mais influentes sobre o tema foram conduzidos com crianças ou adultos falantes do Inglês. **Estratégia de pesquisa:** Uma revisão sistemática foi planejada, conduzida e analisada utilizando as bases de dados PubMed, Science Direct e SciELO. **Critérios de seleção:** A busca da literatura foi conduzida utilizando os termos “phonological processing” e “dyslexia”, nas publicações dos últimos dez anos (2004–2014). **Análise dos dados:** Após a triagem inicial (a) dos títulos e resumos e (b) do texto completo, identificamos 187 artigos que atenderam os critérios de inclusão. **Resultados:** A hipótese do déficit de processamento fonológico foi explorada em estudos envolvendo vários idiomas e, mais importante, em representantes de todos os tipos de sistemas de escrita como o ideográfico, silábico e logográfico, bem como ortografias alfabéticas, com variados níveis de consistência ortográfico-fonológica. **Conclusão:** A hipótese do processamento fonológico foi considerada como explicação válida para a dislexia em uma grande variedade de idiomas e sistemas de escrita.

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**Conflict of interests:** nothing to declare.

## INTRODUCTION

Dyslexia is a neurodevelopmental disorder with a strong genetic predisposition, characterized by specific difficulties in reading and spelling that could not be attributable to cognitive disabilities, lack of educational opportunities, socio-cultural environment, or obvious neurological deficits.

Within the past decades, several theories have been proposed in order to explain the diversity of linguistic and cognitive symptoms observed in developmental dyslexia. These theories conceptualize dyslexia as related to deficits that are either phonological, attentional, visual-magnocellular, auditory, or related to automatic learning<sup>(1)</sup>.

Even though there is a variety of approaches for explaining dyslexia symptoms, phonological processing difficulty has been the major theory explaining such cognitive deficits in dyslexia<sup>(2)</sup>. The phonological deficit hypothesis suggests that reading deficits can be attributed to a core deficit in manipulating linguistic information, at the phonological level, such as phonological awareness, or the ability to determine the constituent sounds which comprise spoken words. This deficit in phonological awareness leads to difficulty in learning grapheme-phoneme correspondences early on and to later difficulty in learning, decoding skills and spelling<sup>(3)</sup>. This evidence has largely come from children with difficulties in learning to read in English, a process that has similarities and differences with other languages<sup>(4)</sup>.

Whether this is a universal model to explain different manifestations, in all ages, spoken or written language contexts remain to be investigated. There have been several different accounts either contradictory or complementary to the phonological processing deficit hypothesis. The majority of studies examining the effects of auditory and visual processing deficits in dyslexia have been conducted in English, an opaque orthography. Therefore, it is essential to determine whether cognitive characteristics, such as the phonological deficits in dyslexia, may differ across languages varying in orthographic consistency.

## PURPOSE

The purpose of the study was to determine whether there is enough evidence in the literature for a phonological processing deficit model for explaining dyslexia, in a wide range of writing systems and orthographies. The approach adopted was a systematic review of studies that relate phonological processing and dyslexia.

## RESEARCH STRATEGY

The central question was to analyse the universal validity of the phonological processing deficit hypothesis for explaining dyslexia, regardless of the spoken language, writing system or age of population. Furthermore, the review describes whether the evidence for phonological processing difficulties comes from experimental, theoretical or intervention studies.

We conducted a search for articles in PubMed, Science Direct and SciELO, published over the past ten years, in Portuguese or English, with the combination of the terms “phonological processing” AND “dyslexia” and their equivalents in Portuguese (“*processamento fonológico*” AND “*dislexia*”). The search was performed using the advanced form, in all indices, with items sorted by relevance. On PubMed and Science Direct, two separate searches were conducted: one considering only the articles with open access and also considering other items with restricted access. For PubMed and Science Direct with restricted access, we selected only the 100 most relevant articles of each database. Duplicated articles were excluded from the final sample.

## SELECTION CRITERIA

We adopted as selection criteria for the analysis the inclusion of complete original articles and review articles, published in the last ten years (from January 2004 to April 2014), in Portuguese or English. The following combination of terms was used for the search: “phonological processing” AND “dyslexia” and their corresponding terms in Portuguese “*processamento fonológico*” AND “*dislexia*”. We included general studies on dyslexia and other known comorbidities, such as attention deficit hyperactive disorder (ADHD), specific language impairment (SLI), dyscalculia and dysgraphia. We excluded repeated articles, articles that were not related to the topic, publications on acquired dyslexia, aphasia, psychiatric or neurological diseases, as well as other irrelevant topics for the current discussion (reading difficulties in Down syndrome, Williams syndrome etc.).

## DATA ANALYSIS

Initially, the first 100 articles were selected according to the relevance in each database. The first inspection for the criteria was based on reading the titles and abstracts of the open access articles. All repeated articles were excluded as well as those not relevant to the discussion. The same procedure was taken for the restricted access articles. When there was any doubt on the exclusion criteria, a second judge analysed the article. The three authors for this study served as judges for the inclusion or exclusion of the articles. If two of the three judges agreed, the article was excluded or included. When the final database for analysis was completed, all articles were read completely in order to register all relevant details for further analysis. The studies were organized by journal, year of publication, population age, spoken and written language, main goal, experimental approach, type of study (theoretical, assessment, intervention etc.), measures used, and conclusions. In the present study, we concentrated on the discussion of the spoken language and writing system.

## RESULTS

The data was retrieved by means of a systematic review of the literature on PubMed (3.1 million articles), Science Direct (12,503,365 articles), and SciELO (478,674 articles).

Considering the search for open access articles, we located 74 articles on PubMed, 106 on Science Direct and 12 articles on SciELO, 8 articles using the terms in English and 4 articles considering the search in Portuguese.

From the open access of PubMed database, we excluded 27 articles, 10 for not following the inclusion criteria, 9 for having different goals from the present study, 3 were repeated in other database, 2 were published in a language other than English or Portuguese and 3 for the type of study (case study).

From the open access of Science Direct database, we excluded 92 articles, 67 for not following the inclusion criteria, 11 for having different goals from the present study, 3 were repeated in other database, 5 were published in a language other than English or Portuguese and 6 for the type of study (case study).

From the SciELO database, when using the search of terms in English, we excluded 2 articles (one for the language of publication and one for the type of study). When using the search terms in Portuguese, we excluded 3 articles for repetition.

This way, at final analysis, we included 47 articles from PubMed, 14 articles from Science Direct and 7 articles from SciELO, in a total of 68 articles with open access.

Considering the articles found in restricted access, we selected the 100 most relevant ones, from PubMed and Science Direct. The repeated articles found in other database or at the open access were excluded. From the database PubMed, we excluded 41 articles, 7 for not following the inclusion criteria, 12 for having different goals from the present study, 21 were repeated in other database and 1 for the type of study (case study).

From the database Science Direct, we excluded 40 articles, 13 for not following the inclusion criteria, 2 for having different goals from the present study, 18 were repeated in other database and 7 for the type of study (case study). In summary, after inspection we included 59 articles from PubMed and 60 from Science Direct, a total of 119 articles from restricted access. The articles found on the SciELO database are all in open access, therefore, there were no articles found on the restricted access group.

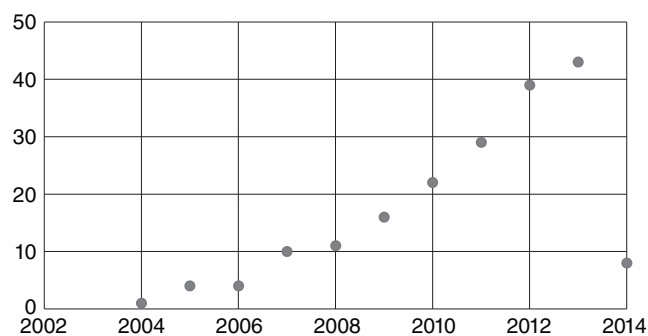
A total of 187 articles were registered and classified according to the categories chosen for further analysis (Table 1). The complete list is in Appendix 1.

**Table 1.** Total number of articles found on the general search and the final number of articles after exclusions

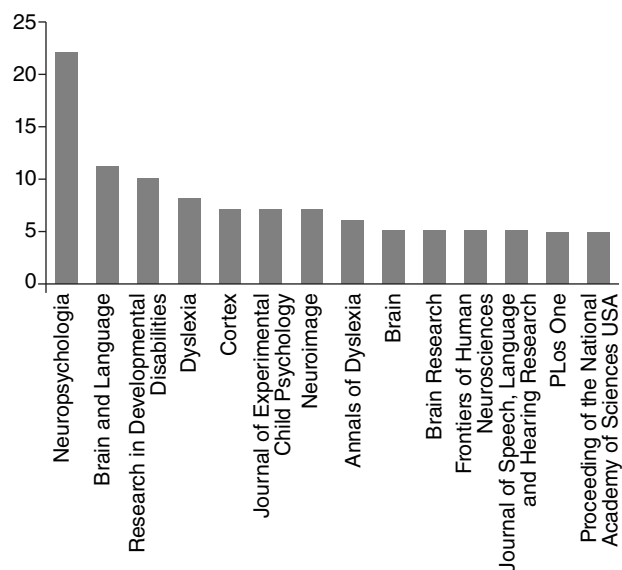
	PubMed	Science Direct	SciELO	Final number
<b>Open access</b>				
Total found	74	106	12	192
Excluded	27	92	5	124
Included	47	14	7	68
<b>Restricted access</b>				
Total found	100	100	–	200
Excluded	41	40	–	81
Included	59	60	–	119
Total included	106	74	7	187

In terms of the distribution of years of publication, there is a clear tendency of increasing the number of articles after 2009 (Figure 1). It is important to note that this review was performed on April 2014, which explains the low number of articles found in that specific year.

We found that the selected articles were published in 70 different periodicals in total, but only 14 have published five or more articles from 2004 to 2014. Figure 2 shows that *Neuropsychologia* is the journal with the greater number of articles (n=22).

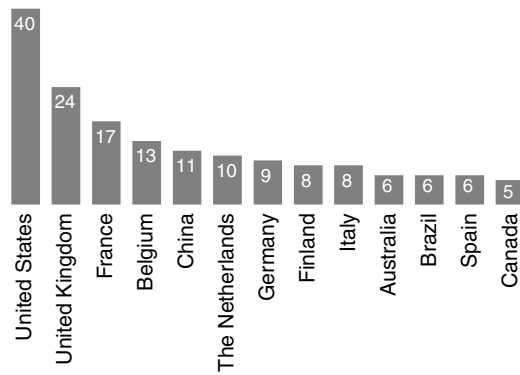


**Figure 1.** Distribution of publications on phonological processing and dyslexia between 2004 and 2014, by year of publication



**Figure 2.** Distribution of journals with more than five publications on the topic "phonological processing" AND "dyslexia," between 2004 and 2014

Several countries contributed for the discussion on whether phonological processing deficit is a universal theory for explaining dyslexia. As shown in Figure 3, The United States (n=40) and United Kingdom (n=24) were the two more productive countries in terms of publications. Brazil was the only country in South America with scientific publications on the topic (n=6).



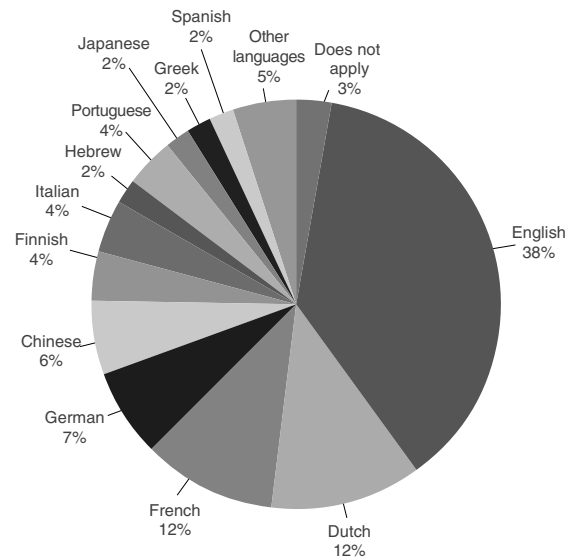
**Figure 3.** Countries of first authors in the publications

Regarding the spoken languages, after inspection of all articles selected in this review, we identified 18 different languages represented. Out of the 187 articles, three studies investigated phonological processing deficits in bilingual populations (Finish-Swedish; Spanish-Swedish; English-Chinese) and one study compared phonological skills in dyslexic Spanish-, English- and Chinese-speaking children. Six articles were characterized as theoretical reviews, so there was not a specific language being investigated. Table 2 depicts the 11 most frequent languages studied. English speaking was responsible for 42% of the studies found in this review, as shown in Figure 4.

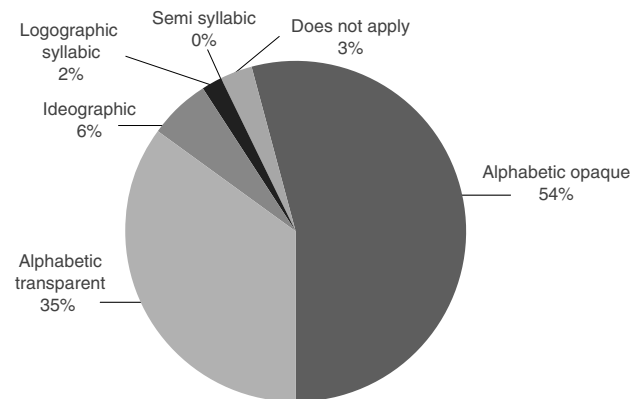
Finally, after inspection of all articles, we registered five writing system classifications: alphabetic opaque, alphabetic transparent, ideographic, logographic-syllabic, and semi-syllabic (Figure 5). The most frequent writing system was alphabetic opaque (53%) but alphabetic transparent orthographies were present in 34% of the publications. The evidence of the relation between phonological processing disorders and dyslexia comes from clinical studies, both in evaluation and intervention studies.

**Table 2.** Distribution of most frequent languages investigated

Languages	Number of articles	%
English	71	38
Dutch	22	12
French	21	11
German	13	7
Chinese	11	6
Finnish	7	4
Italian	7	4
Portuguese	7	4
Hebrew	4	2
Japanese	3	2
Spanish	3	2
Greek	3	2
Other languages	9	5
Does not apply	6	3
Total	187	100



**Figure 4.** Distribution of articles according to the language investigated



**Figure 5.** Distribution of writing systems and their classifications represented in the review

## DISCUSSION

There is a wide spread knowledge on the phonological difficulties found in individuals with dyslexia. Some authors claim that underlying phonological processing deficits would exist for all languages, but that there would be differences in the severity of written language impairments, due to differences in orthographic consistency<sup>(5)</sup>. In other words, we investigated whether this hypothesis also holds for dyslexia in more consistent orthographies, since the phonological code is more accessible in these languages, unlike in English. The present study had the purpose to explore, with a systematic review of the literature, the relation of phonological processing deficits hypothesis with dyslexia, in terms of their universal validity.

The results show a steady increase in publications from 2004 to 2014, which indicates the relevance of the debate and the need for understanding the origin of dyslexia in recent years. From the 187 articles, some are theoretical in nature<sup>(6)</sup>, others describe intervention programs based on phonological abilities<sup>(7)</sup>, and most of them are experimental or clinical studies<sup>(8,9)</sup>.

In terms of the numbers of articles published, we found a wide variety of periodicals with relevant publications showing the interdisciplinary status of the discussion. The papers were found in journals representing the following areas of interest: Education, Psychology, Speech-Language Pathology, Audiology, Linguistics, and Computer Sciences.

To investigate the nature of word reading in various languages, a meta-analysis provided support for the existence of a universal reading network consisting of the left superior temporal gyrus (LSTG), the left inferior frontal gyrus (LIFG), the left occipitotemporal region, and the midfusiform Gyrus<sup>(10)</sup>. The results of this systematic review show that the universal nature of reading holds for reading disabilities, such as the ones found in dyslexia. The phonological nature of such deficits is evident for different spoken languages and different types of writing systems and orthographies<sup>(11)</sup>.

From the studies selected in the present review, it is clear that reading problems associated with dyslexia differ in regular orthographies such as Finnish<sup>(12)</sup> as compared to less regular orthographies such as French<sup>(13)</sup>. However, the underlying cause found in phonological processing skills holds for all levels of orthographic consistencies.

The relation between phonological and orthographic processing is also explored. In recent studies, the associations between auditory temporal processing and phonological processing, and between visual processing and orthographic processing, have received some support, but a lot of criticism as well<sup>(14)</sup>. Although it is not conclusive from the analysis presented here, only a small number of children with dyslexia have reported auditory or visual processing deficits. This heterogeneity of the dyslexic population may have led to such contrasting results.

The origin of phonological processing abilities in dyslexia remains to be established. Some studies are already investigating whether the failure is found on phonological representations or in the process to access these representations during reading<sup>(15)</sup>. No matter which research approach is chosen, cross-linguistic and multidimensional aspects of dyslexia have to be considered.

## CONCLUSION

The phonological processing hypothesis was a valid explanation for dyslexia symptoms in a wide variety of spoken languages and writing systems.

The findings of this review add to a growing number of studies to suggest that the relationship between phonological abilities and reading is influenced by the characteristics of the

orthography. The exact nature of such phonological deficits should be subjected to cross-linguistic comparisons, taking into account systematic differences of the orthographic and phonological characteristics of the languages.

*\*ALGPN was the principal investigator and responsible for conception and study design, data analysis, interpretation of data, correction of written manuscript and final approval of the version to be published. ECF was responsible for data acquisition, data analysis, manuscript editing, revising the study critically, final approval of the version to be published. JPAB was responsible for data acquisition, data analysis, revising the study critically, final approval of the version to be published.*

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**Appendix 1.** List of the 187 articles included for the analysis

N	Authors	Year	Title	Journal
1.	Bonte and Blomert	2004	Developmental dyslexia: ERP correlates of anomalous phonological processing during spoken word recognition	Cogn Brain Res
2.	Catts et al.	2005	Are specific language impairment and dyslexia distinct disorders?	J Speech Lang Hear Res
3.	Giraud et al.	2005	Auditory evoked potential patterns to voiced and voiceless speech sounds in adult developmental dyslexics with persistent deficits	Cereb Cortex
4.	Fosker and Thierry	2005	Phonological oddballs in the focus of attention elicit a normal P3b in dyslexic adults	Cogn Brain Res
5.	Vinckenbosch et al.	2005	Gray matter alteration in dyslexia: converging evidence from volumetric and voxel-by-voxel MRI analyses	Neuropsychologia
6.	Hoefl et al.	2006	Neural basis of dyslexia: a comparison between dyslexic and nondyslexic children equated for reading ability	J Neurosci
7.	Boets et al.	2006	Auditory temporal information processing in preschool children at family risk for dyslexia: relations with phonological abilities and developing literacy skills	Brain Lang
8.	Boada and Pennington	2006	Deficient implicit phonological representations in children with dyslexia	J Exp Child Psychol
9.	Spironelli et al.	2006	Inverted EEG theta lateralization in dyslexic children during phonological processing	Neuropsychologia
10.	Wehner et al.	2007	Effects of phonological contrast on auditory word discrimination in children with and without reading disability: a magnetoencephalography (MEG) study	Neuropsychologia
11.	Rüsseler et al.	2007	Semantic, syntactic, and phonological processing of written words in adult developmental dyslexic readers: an event-related brain potential study	BMC Neurosci
12.	Shankarnarayan and Maruthy	2007	Mismatch negativity in children with dyslexia speaking Indian languages	Behav Brain Funct
13.	VeUILlet et al.	2007	Auditory processing disorder in children with reading disabilities: effect of audiovisual training	Brain
14.	Roach and Hogben	2007	Impaired filtering of behaviourally irrelevant visual information in dyslexia	Brain
15.	Bruno et al.	2007	Auditory word identification in dyslexic and normally achieving readers	J Exp Child Psychol
16.	Boets et al.	2007	Speech perception in preschoolers at family risk for dyslexia: Relations with low-level auditory processing and phonological ability	Brain Lang
17.	Boets et al.	2007	Auditory processing, speech perception and phonological ability in pre-school children at high-risk for dyslexia: a longitudinal study of the auditory temporal processing theory	Neuropsychologia
18.	Meng et al.	2007	Orthographic and phonological processing in Chinese dyslexic children: an ERP study on sentence reading	Brain Res
19.	Torkildsen et al.	2007	Brain responses to lexical-semantic priming in children at-risk for dyslexia	Brain Lang
20.	Cao et al.	2008	Effective brain connectivity in children with reading difficulties during phonological processing	Brain Lang
21.	Bolger et al.	2008	Differential effects of orthographic and phonological consistency in cortex for children with and without reading impairment	Neuropsychologia
22.	Kibby et al.	2008	A quantitative magnetic resonance imaging analysis of the cerebellar deficit hypothesis of dyslexia	J Child Neurol
23.	Frye et al.	2008	Splenium microstructure is related to two dimensions of reading skill	Neuroreport
24.	Germano and Capellini	2008	Eficácia do programa de remediação auditivo-visual computadorizado em escolares com dislexia	Pró-Fono
25.	Capellini et al.	2008	Relação entre habilidades auditivas e fonológicas em crianças com dislexia do desenvolvimento	Psicol Esc Educ
26.	Seki et al.	2008	Reading ability and phonological awareness in Japanese children with dyslexia	Brain Dev
27.	Ziegler et al.	2008	Developmental dyslexia and the dual route model of reading: simulating individual differences and subtypes	Cognition
28.	Lassus-Sangosse et al.	2008	Sequential or simultaneous visual processing deficit in developmental dyslexia?	Vision Res
29.	Thomson et al.	2008	Rhythmic processing in children with developmental dyslexia: auditory and motor rhythms link to reading and spelling	J Physiol Paris
30.	Spironelli et al.	2008	Dysfunctional hemispheric asymmetry of theta and beta EEG activity during linguistic tasks in developmental dyslexia	Biol Psychol
31.	Miller and Kupfermann	2009	The role of visual and phonological representations in the processing of written words by readers with diagnosed dyslexia: evidence from a working memory task	Ann Dyslexia
32.	Liu et al.	2009	Speech perception deficits by Chinese children with phonological dyslexia	J Exp Child Psychol
33.	Abrams et al.	2009	Abnormal cortical processing of the syllable rate of speech in poor readers	J Neurosci

## Appendix 1. Continuation

N	Authors	Year	Title	Journal
34.	Rapcsak et al.	2009	Phonological dyslexia and dysgraphia: cognitive mechanisms and neural substrates	Cortex
35.	Helenius et al.	2009	Neural processing of spoken words in specific language impairment and dyslexia	Brain
36.	Schochat and Murphy	2009	Correlações entre leitura, consciência fonológica e processamento temporal auditivo	Pró-Fono
37.	Germano et al.	2009	Relação entre achados em neuroimagem, habilidades auditivas e metafonológicas em escolares com dislexia do desenvolvimento	Rev Soc Bras Fonoaudiol
38.	Vidyasagar and Pammer	2009	Dyslexia: a deficit in visuo-spatial attention, not in phonological processing	Trends Cogn Sci
39.	Blau et al.	2009	Reduced neural integration of letters and speech sounds links phonological and reading deficits in adult dyslexia	Curr Biol
40.	Matthews and Martin	2009	Electrophysiological indices of spatial attention during global/local processing in good and poor phonological decoders	Brain Lang
41.	Conlon et al.	2009	Relationships between global motion and global form processing, practice, cognitive and visual processing in adults with dyslexia or visual discomfort	Neuropsychologia
42.	Siok et al.	2009	Developmental dyslexia is characterized by the co-existence of visuospatial and phonological disorders in Chinese children	Curr Biol
43.	Landerl et al.	2009	Dyslexia and dyscalculia: two learning disorders with different cognitive profiles	J Exp Child Psychol
44.	Kibby et al.	2009	The pars triangularis in dyslexia and ADHD: a comprehensive approach	Brain Lang
45.	Laasonen et al.	2012	Project DyAdd: visual attention in adult dyslexia and ADHD	Brain Cogn
46.	Illingworth and Bishop	2009	Atypical cerebral lateralisation in adults with compensated developmental dyslexia demonstrated using functional transcranial Doppler ultrasound	Brain Lang
47.	De Smedt and Boets	2010	Phonological processing and arithmetic fact retrieval: evidence from developmental dyslexia	Neuropsychologia
48.	Blomert and Willems	2010	Is there a causal link from a phonological awareness deficit to reading failure in children at familial risk for dyslexia?	Dyslexia
49.	Jednoróg et al.	2010	Implicit phonological and semantic processing in children with developmental dyslexia: evidence from event-related potentials	Neuropsychologia
50.	Laasonen et al.	2010	Project DyAdd: phonological processing, reading, spelling, and arithmetic in adults with dyslexia or ADHD	J Learn Disabil
51.	Facoetti et al.	2010	Visual spatial attention and speech segmentation are both impaired in preschoolers at familial risk for developmental dyslexia	Dyslexia
52.	Maïonchi-Pino et al.	2010	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	Ann Dyslexia
53.	Facoetti et al.	2010	Multisensory spatial attention deficits are predictive of phonological decoding skills in developmental dyslexia	J Cogn Neurosci
54.	Araújo et al.	2010	Visual rapid naming and phonological abilities: different subtypes in dyslexic children	Int J Psychol
55.	Desroches et al.	2010	Children with reading difficulties show differences in brain regions associated with orthographic processing during spoken language processing	Brain Res
56.	Wimmer et al.	2010	A dual-route perspective on poor reading in a regular orthography: an fMRI study	Cortex
57.	Landi et al.	2010	An fMRI study of multimodal semantic and phonological processing in reading disabled adolescents	Ann Dyslexia
58.	Vandermosten et al.	2010	Adults with dyslexia are impaired in categorizing speech and nonspeech sounds on the basis of temporal cues	Proc Natl Acad Sci U S A
59.	Savill and Thierry	2010	Electrophysiological evidence for impaired attentional engagement with phonologically acceptable misspellings in developmental dyslexia	Frontiers in psychology
60.	Boscarol et al.	2010	Processamento temporal auditivo: relação com dislexia do desenvolvimento e malformação cortical	Pró-Fono
61.	Oliveira et al.	2010	Avaliação de um programa computadorizado para intervenção fônica na dislexia do desenvolvimento	Psico-USF
62.	Georgiou et al.	2010	Auditory temporal processing and dyslexia in an orthographically consistent language	Cortex
63.	Leppänen et al.	2010	Newborn brain event-related potentials revealing atypical processing of sound frequency and the subsequent association with later literacy skills in children with familial dyslexia	Cortex
64.	Schulte-Körne and Bruder	2010	Clinical neurophysiology of visual and auditory processing in dyslexia: a review	Clin Neurophysiol
65.	Penolazzi et al.	2010	Brain plasticity in developmental dyslexia after phonological treatment: a beta EEG band study	Behav Brain Res

## Appendix 1. Continuation

N	Authors	Year	Title	Journal
66.	Wang et al.	2010	The visual magnocellular pathway in Chinese-speaking children with developmental dyslexia	Neuropsychologia
67.	Lallier et al.	2010	Behavioral and ERP evidence for amodal sluggish attentional shifting in developmental dyslexia	Neuropsychologia
68.	Menghini et al.	2010	Different underlying neurocognitive deficits in developmental dyslexia: a comparative study	Neuropsychologia
69.	Ho et al.	2011	Early difficulties of Chinese preschoolers at familial risk for dyslexia: deficits in oral language, phonological processing skills, and print-related skills	Dyslexia
70.	Savill and Thierry	2011	Reading for sound with dyslexia: evidence for early orthographic and late phonological integration deficits	Brain Res
71.	Tanaka et al.	2011	The brain basis of the phonological deficit in dyslexia is independent of IQ	Psychol Sci
72.	Brooks et al.	2011	Letter naming and letter writing reversals in children with dyslexia: momentary inefficiency in the phonological and orthographic loops of working memory	Dev Neuropsychol
73.	Lindgrén and Laine	2011	Cognitive-linguistic performances of multilingual university students suspected of dyslexia	Dyslexia
74.	McLean et al.	2011	Visual temporal processing in dyslexia and the magnocellular deficit theory: the need for speed?	J Exp Psychol Hum Percept Perform
75.	Poelmans et al.	2011	Reduced sensitivity to slow-rate dynamic auditory information in children with dyslexia	Res Dev Disabil
76.	Goswami et al.	2011	Language-universal sensory deficits in developmental dyslexia: English, Spanish, and Chinese	J Cogn Neurosci
77.	Froyen et al.	2011	Evidence for a specific cross-modal association deficit in dyslexia: an electrophysiological study of letter-speech sound processing	Dev Sci
78.	van der Mark et al.	2011	The left occipitotemporal system in reading: disruption of focal fMRI connectivity to left inferior frontal and inferior parietal language areas in children with dyslexia	Neuroimage
79.	Lehongre et al.	2011	Altered low- $\gamma$ sampling in auditory cortex accounts for the three main facets of dyslexia	Neuron
80.	Hämäläinen et al.	2011	N1, P2 and T-complex of the auditory brain event-related potentials to tones with varying rise times in adults with and without dyslexia	Int J Psychophysiol
81.	You et al.	2011	Neural deficits in second language reading: fMRI evidence from Chinese children with English reading impairment	Neuroimage
82.	Richardson et al.	2011	Auditory short-term memory capacity correlates with gray matter density in the left posterior STS in cognitively normal and dyslexic adults	J Cogn Neurosci
83.	Perrachione et al.	2011	Human voice recognition depends on language ability	Science
84.	Johnson et al.	2011	Sensitivity to structure in the speech signal by children with speech sound disorder and reading disability	J Commun Disord
85.	Strong et al,	2011	A systematic meta-analytic review of evidence for the effectiveness of the 'Fast ForWord' language intervention program	J Child Psychol Psychiatry
86.	Messaoud-Galusi et al.	2011	Investigating speech perception in children with dyslexia: is there evidence of a consistent deficit in individuals?	J Speech Lang Hear Res
87.	Hoefl et al.	2011	Neural systems predicting long-term outcome in dyslexia	Proc Natl Acad Sci U S A
88.	Araújo et al.	2011	What does rapid naming tell us about dyslexia?	Avances en Psicología Latinoamericana
89.	Dujardin et al.	2011	Behavioral performances in participants with phonological dyslexia and different patterns on the N170 component	Brain Cogn
90.	Raschle et al.	2011	Structural brain alterations associated with dyslexia predate reading onset	Neuroimage
91.	Vandermosten et al.	2011	Impairments in speech and nonspeech sound categorization in children with dyslexia are driven by temporal processing difficulties	Res Dev Disabil
92.	Huss et al.	2011	Music, rhythm, rise time perception and developmental dyslexia: perception of musical meter predicts reading and phonology	Cortex
93.	Nittrouer et al.	2011	What is the deficit in phonological processing deficits: auditory sensitivity, masking, or category formation?	J Exp Child Psychol
94.	Koeda et al.	2011	Dyslexia: advances in clinical and imaging studies	Brain Dev
95.	Stefanics et al.	2011	Auditory sensory deficits in developmental dyslexia: a longitudinal ERP study	Neuroimage
96.	Khana et al.	2011	Auditory event-related potentials show altered hemispheric responses in dyslexia	Neurosci Lett
97.	Moore et al.	2011	Adults with dyslexia exhibit large effects of crowding, increased dependence on cues, and detrimental effects of distractors in visual search tasks	Neuropsychologia



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N	Authors	Year	Title	Journal
98.	Valdois et al.	2012	Impaired letter-string processing in developmental dyslexia: what visual-to-phonology code mapping disorder?	Dyslexia
99.	Georgiou et al.	2012	Are auditory and visual processing deficits related to developmental dyslexia?	Dyslexia
100.	Savill and Thierry	2012	Decoding ability makes waves in reading: deficient interactions between attention and phonological analysis in developmental dyslexia	Neuropsychologia
101.	Wang et al.	2012	Cognitive processing skills and developmental dyslexia in Chinese	J Learn Disabil
102.	Poelmans et al.	2012	Auditory steady state cortical responses indicate deviant phonemic-rate processing in adults with dyslexia	Ear Hear
103.	Chobert et al.	2012	Deficit in the preattentive processing of syllabic duration and VOT in children with dyslexia	Neuropsychologia
104.	Vandewalle et al.	2012	Development of phonological processing skills in children with specific language impairment with and without literacy delay: a 3-year longitudinal study	J Speech Lang Hear Res
105.	Hedman	2012	Profiling dyslexia in bilingual adolescents	Int J Speech Lang Pathol
106.	Steinbrink et al.	2012	Neural correlates of temporal auditory processing in developmental dyslexia during German vowel length discrimination: an fMRI study	Brain Lang
107.	Heim et al.	2012	Interaction of phonological awareness and 'magnocellular' processing during normal and dyslexic reading: behavioural and fMRI investigations	Dyslexia
108.	Laasonen et al.	2012	Project DyAdd: classical eyeblink conditioning in adults with dyslexia and ADHD	Exp Brain Res
109.	Ziegler et al.	2012	Global and local pitch perception in children with developmental dyslexia	Brain Lang
110.	Olulade et al.	2012	Beyond phonological processing deficits in adult dyslexics: atypical FMRI activation patterns for spatial problem solving	Dev Neuropsychol
111.	Maïonchi-Pino et al.	2012	Are syllabification and resyllabification strategies phonotactically directed in French children with dyslexia? A preliminary report	J Speech Lang Hear Res
112.	Lázaro	2012	A study of base frequency in Spanish skilled and reading-disabled children: all children benefit from morphological processing in defining complex pseudowords	Dyslexia
113.	Fuchs et al.	2012	First-grade cognitive abilities as long-term predictors of reading comprehension and disability status	J Learn Disabil
114.	Kovelman et al.	2012	Brain basis of phonological awareness for spoken language in children and its disruption in dyslexia	Cereb Cortex
115.	Vandermosten et al.	2012	A tractography study in dyslexia: neuroanatomic correlates of orthographic, phonological and speech processing	Brain
116.	Berent et al.	2012	Dyslexia impairs speech recognition but can spare phonological competence	PLoS One
117.	Hornickel et al.	2012	Assistive listening devices drive neuroplasticity in children with dyslexia	Proc Natl Acad Sci U S A
118.	Díaz et al.	2012	Dysfunction of the auditory thalamus in developmental dyslexia	Proc Natl Acad Sci U S A
119.	Sela et al.	2012	A working memory deficit among dyslexic readers with no phonological impairment as measured using the n-back task: an fNIR study	PLoS One
120.	Pennington et al.	2012	Individual prediction of dyslexia by single versus multiple deficit models	J Abnorm Psychol
121.	Raschle et al.	2012	Functional characteristics of developmental dyslexia in left-hemispheric posterior brain regions predate reading onset	Proc Natl Acad Sci U S A
122.	Callens et al.	2012	Cognitive profile of students who enter higher education with an indication of dyslexia	PLoS One
123.	Liu et al.	2012	Similar alterations in brain function for phonological and semantic processing to visual characters in Chinese dyslexia	Neuropsychologia
124.	Hasko et al.	2012	N300 indexes deficient integration of orthographic and phonological representations in children with dyslexia	Neuropsychologia
125.	Partanen et al.	2012	Cortical basis for dichotic pitch perception in developmental dyslexia	Brain Lang
126.	Papadopoulos et al.	2012	Low-level deficits in beat perception: Neither necessary nor sufficient for explaining developmental dyslexia in a consistent orthography	Res Dev Disabil
127.	Noordenbos et al.	2012	Neural evidence of allophonic perception in children at risk for dyslexia	Neuropsychologia
128.	Dole et al.	2012	Speech-in-noise perception deficit in adults with dyslexia: Effects of background type and listening configuration	Neuropsychologia
129.	Noordenbos et al.	2012	Allophonic mode of speech perception in Dutch children at risk for dyslexia: a longitudinal study	Res Dev Disabil
130.	Chung et al.	2012	Evidence for a deficit in orthographic structure processing in Chinese developmental dyslexia: an event-related potential study	Brain Res
131.	Kohnen et al.	2012	When 'slime' becomes 'smile': developmental letter position dyslexia in English	Neuropsychologia

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N	Authors	Year	Title	Journal
132.	Aguilar-Vafaie et al.	2012	A comparative study of rapid naming and working memory as predictors of word recognition and reading comprehension in relation to phonological awareness in Iranian dyslexic and normal children	Procedia Soc Behav Sci
133.	Mejia et al.	2012	BEDA: a computerized assessment battery for dyslexia in adults	Procedia Soc Behav Sci
134.	Olofsson et al.	2012	Learning and study strategies in university students with dyslexia: implications for teaching	Procedia Soc Behav Sci
135.	Aboras et al.	2012	Development of a remediation program for Egyptian dyslexic children	AJM
136.	Rello et al.	2012	A mobile application for displaying more accessible eBooks for people with dyslexia	Procedia Comput Sci
137.	Lallier et al.	2013	Developmental dyslexia: exploring how much phonological and visual attention span disorders are linked to simultaneous auditory processing deficits	Ann Dyslexia
138.	Robertson et al.	2013	Past-tense morphology and phonological deficits in children with dyslexia and children with language impairment	J Learn Disabil
139.	Cantiani et al.	2013	Characterizing the morphosyntactic processing deficit and its relationship to phonology in developmental dyslexia	Neuropsychologia
140.	Park and Lombardino	2013	Relationships among cognitive deficits and component skills of reading in younger and older students with developmental dyslexia	Res Dev Disabil
141.	Kita et al.	2013	Altered brain activity for phonological manipulation in dyslexic Japanese children	Brain
142.	Desroches et al.	2013	Electrophysiological indices of phonological impairments in dyslexia	J Speech Lang Hear Res
143.	Goswami et al.	2013	Perception of patterns of musical beat distribution in phonological developmental dyslexia: significant longitudinal relations with word reading and reading comprehension	Cortex
144.	Noordenbos et al.	2013	Deviant neural processing of phonotactic probabilities in adults with dyslexia	Neuroreport
145.	Berent et al.	2013	Phonological generalizations in dyslexia: the phonological grammar may not be impaired	Cogn Neuropsychol
146.	Zaidan and Baran	2013	Gaps-in-noise (GIN©) test results in children with and without reading disabilities and phonological processing deficit	Int J Audiol
147.	Olulade et al.	2013	Abnormal visual motion processing is not a cause of dyslexia	Neuron
148.	Bloom et al.	2013	Planum temporale morphology in children with developmental dyslexia	Neuropsychologia
149.	Bruno et al.	2013	Phonological processing is uniquely associated with neuro-metabolic concentration	Neuroimage
150.	Trecy et al.	2013	Impaired short-term memory for order in adults with dyslexia	Res Dev Disabil
151.	Doignon-Camus et al.	2013	Evidence for a preserved sensitivity to orthographic redundancy and an impaired access to phonological syllables in French developmental dyslexics	Ann Dyslexia
152.	Kronshabel et al.	2013	Visual print tuning deficits in dyslexic adolescents under minimized phonological demands	Neuroimage
153.	Giraud and Ramus	2013	Neurogenetics and auditory processing in developmental dyslexia	Curr Opin Neurobiol
154.	Lallier et al.	2013	On the importance of considering individual profiles when investigating the role of auditory sequential deficits in developmental dyslexia	Cognition
155.	van Zuijen et al.	2013	Infant ERPs separate children at risk of dyslexia who become good readers from those who become poor readers	Dev Sci
156.	Jones et al.	2013	Dyslexia and fluency: parafoveal and foveal influences on rapid automatized naming	J Exp Psychol Hum Percept Perform
157.	Berninger et al.	2013	Teaching children with dyslexia to spell in a reading-writers' workshop	Ann Dyslexia
158.	Mundy and Carroll	2013	Spelling-stress regularity effects are intact in developmental dyslexia	Q J Exp Psychol (Hove)
159.	Yang et al.	2013	Orthographic influences on division of labor in learning to read Chinese and English: insights from computational modeling	Biling (Camb Engl)
160.	Dole et al.	2013	Gray and white matter distribution in dyslexia: a VBM study of superior temporal gyrus asymmetry	PLoS One
161.	Boets et al.	2013	Intact but less accessible phonetic representations in adults with dyslexia	Science
162.	Lallier et al.	2013	Investigating the role of visual and auditory search in reading and developmental dyslexia	Front Hum Neurosci
163.	Hasko et al.	2013	The time course of reading processes in children with and without dyslexia: an ERP study	Front Hum Neurosci
164.	White-Schwoch and Kraus	2013	Physiologic discrimination of stop consonants relates to phonological skills in pre-readers: a biomarker for subsequent reading ability?	Front Hum Neurosci
165.	Power et al.	2013	Neural entrainment to rhythmic speech in children with developmental dyslexia	Front Hum Neurosci
166.	Soltész et al.	2013	Differential entrainment of neuroelectric delta oscillations in developmental dyslexia	PLoS One
167.	Maïonchi-Pino et al.	2013	Is the phonological deficit in developmental dyslexia related to impaired phonological representations and to universal phonological grammar?	J Exp Child Psychol

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N	Authors	Year	Title	Journal
168.	Noordenbosn et al.	2013	Aberrant N400 responses to phonological overlap during rhyme judgments in children at risk for dyslexia	Brain Res
169.	Mahé et al.	2013	Is the impaired N170 print tuning specific to developmental dyslexia? A matched reading-level study with poor readers and dyslexics	Brain Lang
170.	Wang et al.	2013	Learner-generated drawing for phonological and orthographic dyslexic readers	Res Dev Disabil
171.	Peterson et al,	2013	Subtypes of developmental dyslexia: Testing the predictions of the dual-route and connectionist frameworks	Cognition
172.	Goswami et al.	2013	Impaired perception of syllable stress in children with dyslexia: a longitudinal study	J Mem Lang
173.	Nittrouer and Lowenstein	2013	Perceptual organization of speech signals by children with and without dyslexia	Res Dev Disabil
174.	Plakas et al.	2013	Impaired non-speech auditory processing at a pre-reading age is a risk-factor for dyslexia but not a predictor: an ERP study	Cortex
175.	van Ermingen-Marbach et al.	2013	Distinct neural signatures of cognitive subtypes of dyslexia with and without phonological deficits	NeuroImage
176.	Finn et al.	2013	Disruption of functional networks in dyslexia: a whole-brain, data-driven analysis of connectivity	Biol Psychiatry
177.	Lum et al.	2013	Procedural learning is impaired in dyslexia: evidence from a meta-analysis of serial reaction time	Res Dev Disabil
178.	Ghani and Gathercole	2013	Working memory and study skills: a comparison between dyslexic and non-dyslexic adult learners	Procedia Soc Behav Sci
179.	Johnson et al.	2013	Lateralized auditory brain function in children with normal reading ability and in children with dyslexia	Neuropsychologia
180.	Varvara et al.	2014	Executive functions in developmental dyslexia	Front Hum Neurosci
181.	Zhou et al.	2014	Development of reading-related skills in Chinese and English among Hong Kong Chinese children with and without dyslexia	J Exp Child Psychol
182.	Ramus	2014	Neuroimaging sheds new light on the phonological deficit in dyslexia	Trends Cogn Sci
183.	Litt and Nation	2014	The nature and specificity of paired associate learning deficits in children with dyslexia	J Mem Lang
184.	Hämäläinen et al.	2014	Event-related potentials to tones show differences between children with multiple risk factors for dyslexia and control children before the onset of formal reading instruction	Int J Psychophysiol
185.	Kim et al.	2014	Investigating graph comprehension in students with dyslexia: an eye tracking study	Res Dev Disabil
186.	Kalyvioti and Mikropoulos	2014	Virtual environments and dyslexia: a literature review	Procedia Comput Sci
187.	Leong and Goswami	2014	Assessment of rhythmic entrainment at multiple timescales in dyslexia: evidence for disruption to syllable timing	Hear Res