Early identification and intervention in children at risk for reading difficulties
Regtvoort, A.G.F.M.

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Even later kreeg de olifant die brief.

Die is van de egel, dacht hij. Maar hij maakte hem niet open. Lezen, met al die andere letters dan de w, daar hield hij niet van. Ik leg hem vanavond onder mijn hoofd, dacht hij. Dan hoor ik wel wat erin staat.

Uit: Toon Tellegen (2002), 'Misschien wisten zij alles' (p. 375)
Chapter 4

Picture-primed word processing in children at familial risk of dyslexia: Behavioural and electrophysiological outcome following intervention in kindergarten

In case of weak phonemic skills word recognition may be beneficially affected by pictorial priming facilitating the integration of phonological and orthographic information. To examine the effect of congruency priming on strength of activation and topographic distribution, event-related potentials to word-picture pairs were recorded in five-year-old beginning readers at-risk for familial dyslexia (N = 27), all being participants in early intervention and divided into two groups based on emergent literacy skills. Whereas level-related behavioural group differences became smaller, in the time window related to phonological recoding (280-400 ms), priming modulated the topographic distribution such that the group difference to unprimed words was absent to picture-primed words. In the 560-700 ms time window however, only the high-literacy group showed indications of tuning of attentional and integrative processes as a function of congruency. Atypical neural responding related to integration of congruent information seems to mark already at kindergarten age the beginning of reading difficulties.

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4.1 Introduction

During the first stages of reading acquisition, effortful recoding attempts based on grapheme-to-phoneme conversion combined with development of phonemic awareness and phonological analysis skills have a critical impact on reading progress (Liberman, Shankweiler, Fischer, & Carter, 1974; Vellutino, Fletcher, Snowling, & Scanlon, 2004). Unfortunately, children at risk for dyslexia often possess phonological representations that are rather of poor quality or ‘indistinct’ (Elbro, 1998), which impede the mappings of orthography onto phonology (Harm & Seidenberg, 1999; Harm, McCandliss, & Seidenberg, 2003). Learning and stabilization of the major grapheme-phoneme connections into memory may then prove the first obstacle in their reading progress. Even more of a challenge appears to be the ability to extract phonological information from a string of letters so as to blend it, and pronounce it correctly and fluently as a whole word. This applies even to children who have difficulty learning to read in a relatively transparent orthography like Dutch (de Jong & van der Leij, 2003). The development of reading and spelling of those children may therefore be described as slow, lacking the normal characteristics and outcome of skill building.

Developmental dyslexia is primarily considered a language disorder, with a majority of dyslexics showing impaired phonological processing (Pennington, Van Orden, Smith, Green, & Haith, 1990; Ramus et al., 2003). Apparently, dyslexic decoding and spelling problems cannot be contributed to a general dysfunction in a particular brain region (e.g., Simos, Breier, Fletcher, Bergman, & Papanicolaou, 2000). The processing of printed words seems to involve several cognitive mechanisms, and distinct neurophysiological processes are taking place in widely separated, but closely interconnected neural areas (Posner, DiGirolamo, & Fernandez Duque, 1997). Two posterior brain systems in the left hemisphere that seem to play a crucial role in reading and reading development, the ventral located occipitotemporal area and the more dorsal temporoparietal area, are consistently pointed out as being dysfunctional in dyslexia (McCandliss & Noble, 2003; Sandak, Mencl, Frost, & Pugh, 2004).

The gradual developing occipitotemporal visual system appears to predominate in skilled reading and is assumed to be involved with the automatized processing of the orthographic characteristics of a word (e.g., Posner & McCandliss, 1999; Salmelin, Service, Kiesilä, Uutela, & Salonen,
PICTURE-PRIMED WORD PROCESSING IN CHILDREN AT FAMILIAL RISK

1996; Shaywitz et al., 2002). Given its ability for rapid visual analysis of whole words, the left occipitotemporal/fusiform area has been referred to as the ‘visual word form area’ (e.g., Cohen et al., 2000; McCandliss, Cohen, & Dehaene, 2003). During the early processes of visual word recognition, this area shows heightened activation to words as reflected in a left lateralized, occipitotemporal event-related potential (ERP) component. Since automatized processing of words normally develops as a result of reading experience, the characteristic ‘word N1’ that signals the specialization of the occipitotemporal/fusiform area for integration of letter strings apparently is still absent in children learning to read and immature around the age of ten (Brandeis, Vitacco, & Steinhausen, 1994; Posner & McCandliss, 1999). However, by comparing fast visual brain processes to words and symbol strings, a coarse N1 specialisation was observed after one and a half year of formal reading instruction (Maurer et al., 2006), yet at a slower pace of development in dyslexic children than in controls (Maurer et al., 2007).

In becoming a fluent automatized reader, it has been proposed that the ability to recode letters into sounds plays a fundamental role (McCandliss & Noble, 2003). In turn, difficulties in developing decoding skill are assumed to be linked to impaired phonological processing in the second posterior (dorsal) area that is part of the brain network for reading, the temporoparietal system. This system, which predominates during initial reading acquisition, operates in close conjunction with another area, more anterior located in the inferior frontal gyrus (Sandak, Mencl, Frost, & Pugh, 2004). Both areas are involved in phonological recoding (translating the orthographic characteristics into phonological information first) and accessing phonological representations at word level (Paulesu et al., 2001; Shaywitz, 1998; Simos et al., 2002b). Compared to the fast processing ventral system, the level of processing in the dorsal and anterior systems requires attentional resources and is relatively slow (Logan, 1997).

Reading development and outcome may depend heavily on a close interaction between these systems in the reading network (McCandliss & Noble, 2003). In typically developing readers, it is suggested that the limited engagement of the ventral system during the first years of reading acquisition may be compensated for by strong engagement of left hemisphere temporoparietal and frontal areas as well by right hemisphere posterior areas (Sandak et al., 2004). Following effortful recoding attempts and maturation of phonological abilities, commonly the novice reader’s focus of attention moves from grapheme-to-phoneme conversion to the orthographic
regularities in print in order to progress to a more advanced stage of reading. In dyslexic children however, the developmental improvement in reading fluency seems to be impeded by inefficient engagement of left and right hemispheres, as recently reported by Hasko, Bruder, Bartling, & Schulte-Körne (2012). In comparison to the control group, in 11-year-old dyslexic children higher right and reduced left hemisphere activity was found during a phonological-orthographic matching task, and confirmed by the finding that better reading fluency correlated with a reversed activation profile. These results are in agreement with previously observed aberrations in activations profiles in pre-readers at risk for reading problems during a letter-sound task (Simos et al., 2002a), and in various-aged dyslexic children during reading-related tasks that required phonological analysis (Shaywitz et al., 2002). In the latter study, also a correlation between reading skill and degree of activation in left temporal parietal regions was reported. Reduced activation in certain brain areas and/or compensatory activation in others in response to reading (related) tasks may thus reflect deficient phonological analysis (Sandak et al., 2004) or difficulties in accessing (indistinct) phonological representations (e.g., Hasko, Groth, Bruder, Bartling, & Schulte-Körne, 2013) or be the cause of it. Either way, orthographic processing does not become integrated with phonological processing, as is assumed in automatized reading.

Further evidence for the assertion that the key problem in dyslexia might be reduced integration of orthographic and phonological representations comes from recent fMRI research. In a first study, Blau, van Arteveldt, Ekkebus, Goebel, and Blomert (2009) found that dyslexic adults did not suppress cortical activity in superior temporal brain regions to nonexistent pairs of simultaneously presented graphemes and speech sounds. Despite sufficient knowledge about existing letter-sound combinations, their brain activity was not modulated by the incongruency of audio-visual (a-v) pairs, as was the case for the non-dyslexics. Interestingly, in another study with nine-year-old children participating Blau et al. (2010) demonstrated that fluent readers activated the dorsal part of left temporal brain regions more strongly during multisensory processing of congruent letters and speech sounds, whereas this congruency effect was again absent in dyslexic readers. Thus, in both studies brain activity in dyslexic subjects was neither influenced by the inconsistency nor by consistency of the a-v pairs.

In slightly older reading disabled children, Cao, Bitan and Booth (2008) studied rhyming judgments to visually presented word pairs containing
conflicting or not-conflicting orthographic and phonological information in order to examine the modulatory influence of three left hemisphere brain regions (ventral and dorsal posterior, and frontal anterior) and a bilateral frontal region upon another. For conflicting trials, control children differed from children with reading difficulties in effective connectivity, and these modulatory effects were positively related with reading skill only in controls. It was suggested that the weaker or no modulatory effects in impaired readers might reflect deficits in integrating orthography and phonology, especially in case of conflicting information, because children with reading difficulties would be less able to recruit the task-selective regions.

Though superior with respect to spatial resolution, fMRI recording does not allow for conclusions about the timing of the implicated processes (Grünling et al., 2004). Using ERPs, which have a time resolution in the order of milliseconds, Andres, Cardy and Joanisse (2011) examined in adults at what stage of processing integration of letters and their corresponding sounds does occur. Within a stream of standard and deviant letter names, a simultaneously presented visual letter was on occasional trials either congruent or incongruent with the standard or deviant. Compatible with the above reported fMRI findings, ERPs were modulated by congruency. But while incongruent relative to congruent pairs attenuated the pre-attentive mismatch component between 110-190 ms, within the interval of 360-600 ms the P3 component showed an opposite congruency effect, namely an increase to incongruent pairs. Since the P3 is sensitive to focused attention and stimulus categorization, and considered an indicator of difficulty in response selection, according to Andres et al. (2011) this response could best be interpreted as visual letter categorization requiring less processing in case of a letter-sound match.

The current study
To extend the above findings on atypical neural processing in beginning readers at risk for reading problems, the aim of the current ERP study is twofold. Firstly, to assess the facilitating effect that pictorial priming may exert on phonological (sub) processes of printed word identification, and secondly, to examine the differential impact of congruency priming on neural processes associated with a later stage of printed word processing. Hereeto, we manipulated the difficulty of a word recognition task by including congruent and incongruent pairs of words and pictures, in which either the word or the picture was presented as the first stimulus in a pair. To allow for sufficient differentiation in early (pre-)reading skills, and for
inclusion of children who eventually would develop dyslexia, we only selected children at familial risk of dyslexia. Pennington & Lefly (2001) estimated that these children have a chance of about 40% to develop dyslexia, a finding recently replicated (van Bergen et al., 2011). It is important to note that with regard to task-specific environmental reinforcement, major differences in experience were controlled for. When in kindergarten, all subjects took part in a structured home-based training, which was aimed at strengthening of grapheme-phoneme mappings and phonemic awareness in the context of word reading (Regtvoort & van der Leij, 2007).

Notwithstanding the overall advances in (pre-)literacy skills, after training completion children were at most able to read simple words in a no time constraint condition. Interestingly, some of the trained children seemed to profit less from the early ‘boost’ since they did not make as much progress as was expected. Therefore, subsequent to the intervention a word-picture matching design was used to evaluate the impact of the strategy of pictorial priming on early word recognition skills. It is well accepted that a previous exposure to a stimulus can affect the ability to identify a (related) stimulus, in the sense that the altered processing requirements influence accuracy and/or speed of task performance, as well as neural activity (Schacter & Buckner, 1998). Pictorial entities have already shown to be effective primes to words at phonological levels of processing (e.g., Desroches, Newman, & Joanisse, 2009; Peterson & Savoy, 1998), also in electrophysiological studies that focused on neural correlates in children with (familial risk of) dyslexia (Miles & Stelmack, 1994; Torkildsen, Syversen, Simonsen, Moen, & Lindgren, 2007). This might be explained by assuming that if pictures and words share exactly the same meaning, also the same phonological form is shared. So, parallel to the phonological facilitation effect that a homophonic word prime has on word recognition (Lukatela & Turvey, 1994), a picture prime denoting a target word is considered to have a similar effect (Vanderwart, 1984), because “the identical word is already phonologically activated as a response to the picture” (Glaser, 1992, p. 98).

The assumption here is that on primed trials (with homophone picture-word pairs) visual word recognition is facilitated, as shown by more accurate responses and shortened latencies relative to visual word recognition on unprimed trials (with words presented as the first stimulus in a mixed pair). In addition and accordingly, an effect of pictorial priming is reflected by changes at the level of brain functioning, as determined by separate measures
of map strength (indexed by global field power, GPF) and map topography (indexed by positive and negative centroids) (e.g., van Leeuwen et al., 1998). With respect to the early processes of visual word recognition, associated with the activation and retrieval of phonological information, (e.g., Bentin, Mouchetant Rostaing, Giard, Echallier, & Pernier, 1999), we expect neural activity to picture-primed words to be enhanced. It has been argued before that increased responding to difficult to recognize targets might be probable in case the processing of those targets is supported by the prior processing of related and more easily to recognize primes (Henson, 2003). In addition, the bilateral activation in the brain of the picture’s concept (Salmelin, Hari, Lounasmaa, & Sams, 1994) is thought to ease right-to-left hemispheric transition and enhance the engagement of left brain systems upon the subsequent presentation of the target word. Therefore, increased activation might be found in left temporoparietal and frontal regions in particular. Furthermore, given the facilitatory effect of priming on the mapping and integration skills of the children, less processing might be required to analyse the non-conflicting (congruous) stimulus pairs in word-picture matching. Thus in a later time window corresponding to stimulus evaluation time and completion of stimulus categorization (e.g., Kutas, McCarthy, & Donchin, 1977), a reduction in strength of activation, and a congruency-dependent modulation of topographic distribution is expected with respect to prime-induced word recognition.

Providing that facilitated activation of phonological information affects phonological processing efficiency by modulating access to (orthographic-)phonological representations, priming may especially affect phonological encoding in children with low phonemic skills. Expected group differences for unprimed reading in accuracy and/or speed, and/or in modulation of strength and pattern of brain activation related to phonological processes, may then be reduced for primed trials, and accordingly be interpreted as an effect of pictorial priming.

However, it is conceivable that priming may not (fully) compensate for impaired phonological-orthographic connectivity. In such a case, group differences in ability to map and integrate phonological and orthographic information are not entirely abridged by pictorial priming. With regard to brain processes involved in evaluating the congruousness of the paired stimuli, we then expect a differential effect of congruency in terms of lower map strength and modulated brain topography. In line with the suggestion of Cao et al. (2008), that children with better reading skills may also be better at
detecting and resolving conflicting reading-related information, the group with higher (pre-)literacy skills is expected to show such a congruency effect on congruent trials versus incongruent trials, whereas the weaker skilled group will not.

4.2 Method

4.2.1 Subjects

Twenty-seven children with a familial history of reading impairments (8 girls, 19 boys; mean age 6 years, 1 months) were available for measurement. They were in their second year of kindergarten and came from a total of 23 elementary schools in The Netherlands, mostly within the greater area of Amsterdam. All children had (corrected-to-)normal vision; none was diagnosed with serious emotional disturbances. The children’s parents were approached by hand-outs distributed at school. On enrolment, they were requested to fill out an information form. Only families using Dutch as the first language at home were included. Children were being considered at risk in case (1) a parental history of reading problems was reported in the questionnaire, and (2) the parental performance met the inclusion criteria on a screening test, which included two standardized measures of speeded single word and pseudoword decoding, the Een-Minuut-Test (EMT) (Brus & Voeten, 1999) and the Klepel (van den Bos, lutje Spelberg, Scheepstra, & de Vries, 1999) respectively, and the Wechsler Adult Intelligence Scale (WAIS) subtest Similarities (Wechsler, 1997) measuring concept formation. Inclusion criteria held that reading performance of (at least) one parent had to fall below or at the 10th percentile on either one of the reading tests or below or at the 20th percentile on both reading tests. Also leading to selection was a discrepancy of at least 60 percentiles between the score on the subtest Similarities and on either one of the reading tests (Koster et al., 2005).

In The Netherlands, prior to entering first grade, reading and spelling-related skills are not systematically taught. Differentiation of groups with low literacy skills (N = 13, mean age 6 years, 1 months, range 69-79 months, 11 boys) and high literacy skills (N = 14, mean age 6 years, 1 months, range 70-81 months, 8 boys), was therefore determined after a 14-week structured reading program based on the “Word Building” technique (McCandliss, Beck, Sandak, & Perfetti, 2003) and adapted to accommodate Dutch pre-readers (see Regtvoort & van der Leij, 2007 for more details). Literacy
proficiency was assessed using three measures: (1) receptive letter knowledge (Verhoeven, 2000); (2) phonemic awareness consisting of three subtests: phonemic blending (Verhoeven, 1993a), phonemic segmentation (Verhoeven, 1993b), and first-sound identity (Irausquin, n.d.); and (3) unspeeded word decoding (Regtvoort, 2003). Raw scores were converted to percentages of correct responses. Children fell into the high literacy group if they scored at least 50% correct on all three measures. The groups did not differ significantly in gender ratio ($\chi^2 (1) = 2.44, p > .05$) or age ($t(25) = .40, p > .05$). The characteristics, and descriptive and test statistics for the criterion, correlate and control measures appear in Table 4.1.

Table 4.1
Characteristics and mean performance (standard deviations) on parental screening, control and criterion measures, and reading correlate for low and high (pre-)literacy subgroups.

<table>
<thead>
<tr>
<th>Characteristics at kindergarten entry</th>
<th>Low (N = 13)</th>
<th>High (N = 14)</th>
<th>Independent t test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother’s education level (1-7)</td>
<td>4.4</td>
<td>5.4</td>
<td>$t(25) = -2.08^*$</td>
</tr>
<tr>
<td>Father’s education level (1-7)</td>
<td>4.5</td>
<td>6.4</td>
<td>$t(16.03) = -3.67^{**}$</td>
</tr>
<tr>
<td>Dyslexic parent’s education level (1-7)</td>
<td>4.4</td>
<td>5.9</td>
<td>$t(19.38) = -2.90^{**}$</td>
</tr>
<tr>
<td>Non-dyslexic parent’s education level (1-7)</td>
<td>4.5</td>
<td>5.9</td>
<td>$t(25) = -2.70^{*}$</td>
</tr>
<tr>
<td>Amount of storybook reading (1-5)</td>
<td>4.0</td>
<td>4.7</td>
<td>$t(13.95) = -2.43^{*}$</td>
</tr>
<tr>
<td>Number of books in the home (1-5)</td>
<td>3.1</td>
<td>4.5</td>
<td>$t(18.71) = -2.72^{*}$</td>
</tr>
<tr>
<td>Parental screening measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word reading fluency (max = 116)</td>
<td>63.3 (12.8)</td>
<td>73.9 (13.9)</td>
<td>$t(25) = -2.06^{*}$</td>
</tr>
<tr>
<td>Pseudoword reading fluency (max = 116)</td>
<td>40.6 (17.8)</td>
<td>53.3 (14.1)</td>
<td>$t(25) = -2.06^{*}$</td>
</tr>
<tr>
<td>Verbal competence (max = 20)</td>
<td>15.2 (5.5)</td>
<td>18.6 (3.9)</td>
<td>ns</td>
</tr>
<tr>
<td>Control measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receptive vocabulary 1 (max = 96)</td>
<td>71.3 (10.2)</td>
<td>73.4 (8.0)</td>
<td>ns</td>
</tr>
<tr>
<td>Nonverbal IQ 2 (max = 36)</td>
<td>23.2 (5.6)</td>
<td>26.7 (3.8)</td>
<td>ns</td>
</tr>
<tr>
<td>Criterion measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Letter knowledge (per cent correct)</td>
<td>62.5 (12.7)</td>
<td>80.4 (6.5)</td>
<td>$t(25) = -4.65^{***}$</td>
</tr>
<tr>
<td>Phonemic awareness (per cent correct)</td>
<td>39.5 (15.1)</td>
<td>76.1 (13.9)</td>
<td>$t(25) = -6.56^{***}$</td>
</tr>
<tr>
<td>Word decoding accuracy (per cent correct)</td>
<td>32.9 (21.0)</td>
<td>82.9 (15.2)</td>
<td>$t(25) = -7.14^{***}$</td>
</tr>
<tr>
<td>Naming speed (reading correlate) 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colours/objects (averaged total time in ms)</td>
<td>104.7 (27.8)</td>
<td>81.6 (30.5)</td>
<td>$t(25) = 2.37^{*}$</td>
</tr>
</tbody>
</table>

Note. 1 January kindergarten. 2 January Grade 1. 3 June kindergarten; * $p < .05$; ** $p < .01$; *** $p < .001$

For serial rapid naming, another correlate of poor reading (for evidence with regard to Dutch, see de Jong & van der Leij, 2003), scores for objects and colours (van den Bos, lutje Spelberg, & Ruizeveld de Winter, 2003) were computed as averaged total processing times across symbol types, as both
measures loaded high (> .85) on a single component. Naming speed correlated (nearly) significant with two of the criterion (pre-) literacy measures: unspeeded decoding, \( r = -0.40, p < .05 \), and letter knowledge, \( r = -0.38, p = .052 \). Two control measures were used to assess cognitive ability. The groups did not differ significantly on receptive vocabulary (Verhoeven & Vermeer, 2001), nor on non-verbal intelligence (Raven, Court, & Raven, 1984).

The parents of high literacy children were higher educated than the parents of the low literacy children, but within each group, dyslexic and non-dyslexic parents did not differ for education level, ranking from 1 (primary education only) to 7 (university degree). The dyslexic parents of higher literacy children scored slightly better on the reading tests than the dyslexic parent of lower literacy children, but not on verbal competence. The literacy environment (amount of storybook reading, rated from 1 (no storybook reading at all) to 5 (5 or more times a week), and on number of books in the home, rated from 1 (less than fifty) to 5 (more than 200) of the high literacy group was even more stimulating than for the low literacy group. Both groups were as often tutored by the dyslexic as the non-dyslexic parent.

### 4.2.2 Apparatus

A 32-channel electrocap was used employing sintered Ag/AgCl electrodes in a 10-20 system montage including locations Oz, O1/2, Pz, P3/4, P7/8, CPz, CP3/4, TP7/8, Cz, C3/4, T7/8, FCz, FC3/4, FT7/8, Fz, F3/4, F7/8, and Fp1/2. Additional electrodes recorded the vertical electro-oculogram (VEOG; above and below the left eye) and the horizontal electro-oculogram (HEOG; at the outer canthus of each eye). Linked ear electrodes served as the inactive reference. Electrocortical activity was recorded with 500 Hz per channel and filter settings of 0.1-70 Hz (Synamps model 5083, Neuroscan Inc). Impedances were kept below 20 k\( \Omega \) (Ferree, Luu, Russell, & Tucker, 2001).

### 4.2.3 Stimuli

The stimuli consisted of eight CVC words, *pen (pen) - kip (chicken) - kop (cap) - kam (comb) - pet (cat) - pan (pot) - kom (bowl) - pit (apple pit)*, and eight colour drawings depicting the words. The last four words were not used during training. Two additional words and matching pictures were used as practice stimuli. Each of the stimuli could serve as a prime or a target. A majority of
the participants were expected to know how to read the included CVC words\(^1\). A total of 222 stimuli pairs were divided over four conditions, two conditions with mixed stimulus type pairs: 96 word-picture pairs, and 60 picture-word pairs; and two homogeneous stimulus type pairs: 30 word-word pairs, and 36 picture-picture pairs. The number of congruent pairs within these conditions appeared at a probability of 25%, 25%, 30% and 50%, respectively. Congruent stimuli in mixed pairs had the same denotative meaning; in homogeneous pairs it concerned identical stimuli. Pairs were pseudo-randomly presented and divided over three blocks such that each condition and number of congruent pairs appeared proportionally correct. Picture-word pairs consisted only of trained words due to the limited number of trials. To control for attending, picture-picture pairs appeared at least every twelfth pair.

\[\text{Figure 4.1. Experimental task. A mixed series of words and pictures were presented at random order. Trial duration varied from 4250 to 6250 ms depending on the nature of the stimuli within a pair (mixed or homogeneous). The inter-stimulus and the inter-pair interval (in which congruent pairs required a manual response) were kept constant.}\]

Stimulus presentation and sampling procedures were controlled by a standard PC, using Wesp Experimentation Stimulus Program (WESP) (Molenkamp & Hoogervorst, 2002). Words and pictures were presented for 2000 ms and 1000 ms, respectively, in the centre of a screen, which was positioned frontally, at a distance of 100 cm from the subject's eyes (see Figure 4.1). The inter-stimulus interval (ISI) within a pair was held constant.

\[^1\text{The unspeeded word measure administered following intervention consisted of 18 monosyllabic words (none of which included in the experimental task), of which 13 words had not been in the training corpus: eight CVC words and five (C)VCC words, a structure not practised during training. After intervention completion, 8 out of 13 children in the low (pre-)literacy group could read at least 6 (33%) to 10 words correct. In the high (pre-)literacy group, all 14 children read at least 10 (56%) words correct, and 11 children 4 to 18 words.}\]
at 250 ms and the inter-pair interval (IPI) (with black fixation cross) at 2000 ms. Words were displayed in lower case letters with a black 96-point Arial font. Pictures were embedded in a yellow background that subtended a visual angle of about 3.5° in height and in width, or a visual angle of about 3° in height and 4° in width, depending on shape.

4.2.4 Procedure

The ERP recording session took 1-1½ hours. After being familiarized with the procedure, children had to name the eight pictures to ensure they knew the intended names. When necessary, subjects were corrected and retested prior to the actual task execution. During preparation of the electrocap, children could watch a video for distraction. Recording took place in an adjacent room with dimmed lights and closed door. Seated in a comfortable chair, children were given 20 practice trials using two pairs of practice stimuli, prior to the first of three experimental blocks. They had to press a button on either the left or right armrest, depending on the preferred hand, in case of a match between paired stimuli. Children were further instructed to sit as still as possible. A video camera recorded the direction of the child’s gaze. An assistant was present to assure that the child remained fixating the screen centrally. Accompanying parents were only allowed in the recording room during short breaks in between blocks. All children received a present afterwards.

4.2.5 EEG recording and processing

ERPs. The EEG was bandpass filtered (.5-20 Hz, 48 dB/octave) and eye blinks were corrected according to a spatial filter transform based on a linear derivation approach ("Neurosoft Inc.", 2001). Artefacts exceeding 100 µV in any channel were automatically rejected. Epochs (starting 100 ms before stimulus onset and lasting 1024 ms) were obtained separately for ‘unprimed’ words presented as the first stimulus in a pair irrespective of condition, and for ‘picture-primed’ words presented as the second stimulus within the picture-word condition. For picture-primed words only, epochs were obtained separately for two additional stimulus types ‘unrelated’ and ‘related’. Mean number of trials left after artefact rejection for each group and stimulus type (126 unprimed; 60 picture-primed: 46 unrelated, 14 related\(^2\)) were respectively: for low M = 91.2; 45.0: 34.8, 11.4 (range = 69-113; 29-55).\(^2\)

\(^2\) Data of 4 subjects were excluded
23-42, 9-13), for high M = 95.2; 49.9; 37.9, 12.3 (range = 63-119; 31-59; 22-
45, 8-14). Epochs were averaged separately for each subject and individual
averages were then transformed to the average reference across all channels
except for the two EOG channels (Lehmann & Skrandies, 1980).

Figure 4.2. Grand averages of GFP for unprimed words for the low (dashed) and the high
(solid) (pre-)literacy skilled subgroup

Grand averages computed for each condition (see Figure 4.2 for unprimed
words and Figure 4.3 for related picture-primed words) were used to
determine the temporal changes in GFP, a measure calculated as the square
root of the sum of squares of the average-referenced activity over all
electrodes (Lehman & Skrandies, 1980). As a reference-free measure of
cortical activity to which all recording electrodes contribute equally, GFP is a
useful measure to identify the components of brain activity and avoid problems that arise in conventional waveform analysis (see e.g., Skrandies, 2005). Peaks of GFP reflect the maxima of the total underlying brain activity that contributes to the surface potential field (Lehmann & Skrandies, 1984), whereas GFP troughs (minima) can be used to mark topographic transitions as segment borders (Brandeis et al., 1998; Lehmann & Skrandies, 1980). Visual inspection of the grand averages yielded six distinct GFP peaks.

![Figure 4.3. Grand averages of GFP for related picture-primed words, for the low and the high (pre-)literacy skilled subgroup. At the left the enlarged electrodes FP2, Fz and PZ.](image)

Adaptive segmentation according to GFP minima (e.g., Brandeis et al., 1994) for the group’s grand mean ERP for words yielded six sequential segments (also called time windows) with relatively stable map topographies (see Figure 4.4). Based on peak latency and scalp distribution, the first two segments were identified as corresponding to the visual P1/N1 ERP complex, and the fifth to ERP component P3b. For this study we selected three consecutive segments, largely overlapping with peaks 3, 4 and 5: from 280-400 ms and from 400-560 ms both showing an anterior
negative/posterior positive distribution, and from 560-700 ms showing a positive-going modulation maximal at centro-parietal sites. These segments were assumed to cover stages of beginning visual word processing most relevant to this paper, the third segment reflecting phonological word analysis (Bentin et al., 1999; Khateb et al., 1999), and the fourth and fifth segment activation of whole-word phonological representations (Grainger & Holcomb, 2009), followed by a process of event categorization (Kok, 2001).

Figure 4.4. Grand average for all word conditions with butterfly plot and segments (S) 3, 4 and 5 shaded in yellow; at the right topographic maps of segment peaks 1 to 5.

For each segment, the mean strength of activation was computed at the individual level for unprimed and picture-primed words, and for unrelated and related words. To define the topographical characteristics of electrical brain activity for these word conditions, the locations of the centers of gravity of the positive and negative fields (3D centroids, measured from all 30 electrode positions, using a preauricular-nasion (PAN) reference plane
("Neurosoft Inc.," 2001), were computed as in Maurer, Brandeis, & McCandliss (2005).

For an additional analysis regarding picture primes only, GFP peak latency and mean strength were measured for a segment adjusted to 258 to 436 ms based on two GFP minima before and after the third peak of the grand average for pictures.

4.2.6 Statistical analysis

Behavioural data analysis was restricted to matching words. Two separate multivariate analysis of variance (MANOVA) for repeated measures (RM) with within-subjects factor “condition” (3 levels: unprimed; picture-primed; repeated) and between-subjects factor “literacy level” (low (LL) vs. high (HL)) were conducted for accuracy and reaction time. Accuracy was calculated as the difference between the arc sine transformed proportions of correct hits and false alarms (Hochhaus, 1972), so as to take into account the tendency in some children in each group to guess true (matching) when presented with false (non-matching) pairs. Only reaction times to correct responses (hits) were analysed. Two LL children without hits were excluded from reaction time analysis. Simple planned contrasts were included for testing the expectations regarding differences among three levels of condition: picture-primed vs. unprimed, and picture-primed vs. repeated, and among the groups of different literacy level: ‘LL’ vs. ‘HL’.

All ERP analyses included the between-subjects factor “literacy level” (LL vs. HL) to test for between-group differences. Our primary focus was on ERPs of word processing, which were analysed for each of the three selected segments separately. In addition, we also tested latency and mean GFP for picture primes (pictures appearing first in a pair) for one adjusted segment only, using ANOVA. The differential effects on mean GFP and 3D centroids for unprimed word processing were tested using MANOVA. For picture-primed word processing versus unprimed word processing, mean GFP and 3D centroids were analysed separately in repeated measures (RM) MANOVA including within-subject factor “priming” (2 levels: unprimed; picture-primed). To test for the effect of semantic content of picture primes on subsequent word processing, an additional series pertaining to picture-primed words only included within-subject factor “prime type” (unrelated vs. related). Data of four subjects (three LL, one HL) were excluded from the latter analyses due to an insufficient number of qualitative good
‘congruent’ trials. All centroid analyses included the additional factor “polarity” (positive vs. negative). The three spatial coordinates (x-, y-, and z-axes) were treated as multivariate dependent measures (Maurer, Brandeis et al., 2005). To define their position in 3D space, multivariate effects for the coordinates were further analysed with univariate tests. Main and interaction effects of “priming”, “prime type”, and “literacy level” are considered indices of positive and negative centroids showing a similar pattern, and therefore referred to as “centroid mean location”. Interaction effects of “polarity”, as indices that positive and negative centroids show a different pattern, are referred to as “centroid distribution” (Maurer, Brandeis et al., 2005). To test specific hypotheses on between-group differences in positive and negative coordinates, planned contrasts were included in the designs. Reported are significant main effects and polarity interactions at the multivariate level (p < .05) as well as conspicuous univariate between-group differences.

4.3 Results

4.3.1 Behavioural data

The behavioural results for all conditions observed, including repeated picture detection, a control condition omitted from the analyses, are summarized in Table 4.2. For ease of interpretation, the reported data for accuracy represent percentages of hits and false alarms, and not the transformed proportional values as used in the analyses.

Accuracy There was a significant main effect for condition, $F(2, 24) = 35.02$, $p < .001$, which indicated that, overall, subjects performed slightly more accurate for picture-primed as opposed to unprimed words, $F(1, 25) = 3.70$, $p = .066$; and significantly more accurate for repeated as opposed to picture-primed words, $F(1, 25) = 42.39$, $p < .001$. The different conditions affected the HL and LL groups in a similar way, but a main effect for literacy level did confirm group status, $F(1, 25) = 7.81$, $p < .05$. Mean accuracy was higher in the HL group for unprimed words, $F(1, 25) = 5.29$, $p < .05$, and repeated words, $F(1, 25) = 5.84$, $p < .05$, and tended to be higher for picture-primed words, $F(1, 25) = 3.60$, $p = .069$. 
Table 4.2  
Percentages of correct responses and false alarms, and reaction times for hits in the four conditions (unprimed words, picture-primed words, repeated words, and repeated pictures), for groups with low and high literacy skills.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Low Literacy ((N=13))</th>
<th>High Literacy ((N=14))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correct in % (SD)</td>
<td>Hits RT in ms (SD)</td>
</tr>
<tr>
<td>Matching</td>
<td>Unprimed words</td>
<td>21.5 (19.5) 1345 (269) 1339 (320) 7.5 (8.0)</td>
</tr>
<tr>
<td>Detection</td>
<td>Repeated words</td>
<td>68.4 (16.9) 1025 (206) 84.1 (349) 13.3 (13.0)</td>
</tr>
</tbody>
</table>

\(SD\): standard deviation; RT = reaction time; \(1\)N=11; \(2\)N=12.

Reaction times did not interact significantly with literacy, \(F(2,22) = 1.41, p > 1\), and there was no significant main effect for literacy level either, \(F(1,23) = 1.29, p > 1\). However, condition did influence RTs across groups, \(F(2,22) = 25.57, p < .001\), with faster hits times to unprimed and repeated words as opposed to picture-primed words, \(F(1,25) = 11.86, p < .01\), and \(F(1,25) = 50.71, p < .001\). In both groups, detecting repeated words, which did not necessarily involve reading, yielded the fastest hits times of the three word conditions (see Table 4.2).

Table 4.3  
Significant multivariate results of MANOVAs for RM for map strength (GFP) and topography (3D centers of gravity) with Priming (unprimed vs. picture-primed), or Prime Type (unrelated picture-primed vs. related picture-primed) and Literacy level (Low Literacy vs. High Literacy), in three consecutive time segments (S3, S4, S5). The centroid analyses include the additional factor Polarity (positive vs. negative).

<table>
<thead>
<tr>
<th>Time Segment</th>
<th>Strength (GFP)</th>
<th>Topography (3D centroids)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Centroid Mean Location</td>
<td>Centroid Distribution</td>
</tr>
<tr>
<td></td>
<td>Multivariate</td>
<td>Axis</td>
</tr>
<tr>
<td>S3 (280-400 ms)</td>
<td>P, (F(1,23)=93.3^{**})</td>
<td>(F(3,23)=7.0^{**})</td>
</tr>
<tr>
<td>S4 (400-560 ms)</td>
<td>P, (F(1,23)=124.4^{**})</td>
<td>(F(3,23)=10.7^{**})</td>
</tr>
<tr>
<td>S5 (560-700 ms)</td>
<td>P, (F(1,23)=174.4^{**})</td>
<td>(F(3,23)=23.4^{**})</td>
</tr>
</tbody>
</table>

| Prime Type | S3 (280-400 ms) | \(PT, F(1,21)=18.6^{**}\) |
|            | S4 (400-560 ms) | \(PT, F(1,21)=18.1^{**}\) |
|            | S5 (560-700 ms) | \(PT, F(1,21)=19.9^{**}\) | \(PT\-PO, F(3,19)=4.0^{*}\) | \(y^{*}\) |

| Note: | P = Priming; PT = Prime Type; L = Literacy level; PO = Polarity; \(x, y, z = \) univariate significant axis (\(x = \) left–right, \(y = \) anterior–posterior, \(z = \) superior–inferior) \(***p < .001; **p < .01; *p < .05; p < .1\) |
4.3.2 ERP data

Test statistics of significant multivariate main and interaction effects appear in Table 4.3. The corresponding univariate results will be reported in the text.

Picture primes (adjusted segment 258 to 436 ms)

GFP There was no significant effect of literacy level for the latency of the GFP peak or overall map strength observed between 258 and 436 ms, indicating that the LL and HL groups activated phonological processes in response to pictures serving as primes with the same rate and to the same extent.

Unprimed words (segments 3, 4 and 5)

GFP For neither of the segments a significant effect for literacy level was found, so LL and HL children could not be discriminated on the base of overall map strength to unprimed words.

3D centroids There were no significant multivariate differences in topography for literacy level. In time segment 3 (from 280 to 400 ms) however, there was a univariate between-group difference in centroid distribution of the positive and negative y-centroids (literacy level x polarity, $F(1, 25) = 5.20, p < .05$), on account of the positive y centroid being more posterior (HL, $M = -61.19$ mm vs. LL, $M = -38.05$ mm), and the negative y centroid inclining to be more anterior (HL, $M = -1.83$ mm vs. LL, $M = -22.38$ mm). See also Figure 4.5 for the centroid locations and Figure 4.6 for four successive ERP maps, time interval 280 to 400 ms.

Picture-primed as opposed to unprimed words (segments 3, 4 and 5)

GFP In all segments picture-primed words elicited the larger overall map strength as opposed to unprimed words, (see Table 4.3 for significant multivariate test statistics of GFP effects on the factor Priming), but there were no between-group differences in overall map strength on any segment.

3D centroids In all segments also topographic effects to picture-primed and unprimed words were found as indicated by different centroid mean locations and centroid distributions between the levels unprimed and picture-primed (see Table 4.3, Topography), but for neither of the segments the observed differences between unprimed and picture-primed words could be related to literacy level. In segment 3 (280 to 400 ms), different mean locations were found on the y-axis, $F(1, 25) = 14.65, p < .01$ and the z-axis,
Figure 4.5. Positive and negative centroid locations in segment 280 to 400 ms. Subgroup differences (Low Literacy vs. High Literacy) in topography (y-axis) for unprimed but not for picture-primed words. Figure design adapted from Maurer, Brandeis et al. (2005)

Figure 4.6. ERP maps (head seen from above, left ear left) for unprimed (quadrant a, b) and picture-primed (quadrant c, d) words with 40-ms interval in latency range 280 to 400 ms post-stimulus onset, in children with low (pre-)literacy skills (quadrant a, c), as compared to children with high (pre-)literacy skills (quadrant b, d). Subgroup differences were only found for unprimed words.
$F(1, 25) = 7.22, p < .05$, with a more posterior and less superior centroid mean for unprimed than for picture-primed words. The difference in centroid distributions were related to the x-axis, $F(1, 25) = 5.23, p < .05$ and y-axis, $F(1, 25) = 8.43, p < .01$, with positive centroids appearing more right-lateralized and more posterior for picture-primed words than for unprimed words, and negative centroids appearing as left-lateralized and anterior for picture-primed words, and as more right-lateralized and more posterior for unprimed words. See also Figures 4.5 and 4.6.

In segments 4 and 5 (400-560 ms; 560-700 ms), the priming related topographic differences were indicated by different centroid distributions. For segment 4 this distribution difference between the two levels of priming was related to the x-axis, $F(1, 25) = 6.18, p < .05$ and the y-axis, $F(1, 25) = 24.40, p < .001$, with a similar pattern as in segment 3. For segment 5 the distribution effect concerned the difference between positive y centroids appearing more posterior for primed than for unprimed words, whereas negative y centroids were located anterior for primed words, yet posterior for unprimed words, $F(1, 25) = 53.39, p < .001$.

Related as opposed to unrelated picture-primed words (segments 3, 4 and 5) GFP Again significant overall effects for the GFP measure were found in all segments (see Table 3, GFP, Prime Type). Map strength for related picture-primed words was always larger than for unrelated picture-primed words (see Figure 4.7). More importantly, in the last segment there was a not quite significant between-group difference in GFP between the two types of picture-primed words (prime type $\times$ literacy level, $p = .084$). The LL group tended to show a larger increase in overall map strength than the HL group while evaluating semantic content of related picture-primed words as opposed to unrelated picture-primed words.

3D centroids Related and unrelated picture-primed words showed a more or less similar topography, and no significant effects of prime type, and interactions of prime type with polarity were found. In the last segment however, the trend for GFP for prime type with literacy level was accompanied with a significant between-group difference in topography, (see Table 4.3, PT$\times$L$\times$P) on the y-axis, $F(1, 21) = 7.68, p < .05$. Follow-up analyses indicated that only in the HL group the different centroid distributions to unrelated and related picture-prime words reached significance (HL, prime type $\times$ polarity, $F(1, 12) = 6.90, p < .05$). Whereas HL children showed a less
CHAPTER 4

Figure 4.7. Grand averages of GFP for unprimed words (dashed), unrelated picture- 
primed words (thin) and related picture-primed words (bold), for groups with low (left) 
and high (pre-) literacy skills.

Figure 4.8. Positive and negative centroid locations in segment 560 to 700 ms of unrelated 
and related picture-primed words. Topographic subgroup differences are found on the y- 
axis with related words eliciting in children with high literacy skills a less posterior 
positivity and a less anterior negativity compared to unrelated words, whereas children 
with low literacy skills show a reversed, but not significant pattern. Figure design adapted 
from Maurer, Brandeis et al. (2005).

posterior positivity and a less anterior negativity for related words compared 
to unrelated words (HL, positivity, M related = -50.11 mm vs. M unrelated 
= -64.84 mm; negativity M related = 7.76 mm vs. M unrelated = 25.07 mm), 
in LL children a reversed, but not significant pattern was generated (LL, 
positivity, M related = -62.46 mm vs. M unrelated = -55.05 mm; negativity,
M related = 21.89 mm vs. M unrelated = 17.25 mm) (see Figure 4.8). Inspection of topographic maps revealed that unrelated-related distribution differences in HL children were mainly due to the negative centroid being located less frontally for related words (see Figure 4.9).

Figure 4.9. ERP maps (head seen from above, left ear left) for unrelated (quadrant a, b) and related (quadrant c, d) picture-primed words with ±35-ms interval in latency range 580 to 680 ms post-stimulus onset, show the trend for a greater related-unrelated strength difference in children with low literacy skills (quadrant a, c), as compared to children with high literacy skills (quadrant b, d); only in the latter group related primed words elicited a negativity which had a less frontal distribution compared to unrelated primed words.

4.4 Discussion

In the present study, we investigated the impact of pictorial priming on word recognition abilities in kindergarten children at risk for dyslexia, who were identified as having high and low literacy skills following an emergent literacy intervention. The focus lay on the effect of priming on phonological facilitation of word processing by way of improved performance and modulated neural activity to picture-primed words in relation to literacy level. In addition, we considered whether there was literacy-related
modulation of neural activity to trials consisting of pictures and words with the same connotative meaning, which could be explained as a congruency effect.

4.4.1 Effects of pictorial priming on phonological facilitation

Early word recognition appeared to be facilitated by priming with pictures. In matching pictures and words, responses tended to elicit more hits to stimulus pairs in which a picture was serving as a prime to a target word as opposed to mixed pairs in which words were appearing as the first stimulus. The facilitating influence on decoding of picture-primed words over unprimed words was shared by both groups, thus to literacy-level. This finding might suggest that prime-induced pre-activation of the phonological characteristics of the target word reinforced both groups equally to form more accurate orthography-phonology mappings during picture-primed word processing as opposed to unprimed word processing. However, an important part of the children appeared to have difficulty with the word-picture matching task. As they all were in the very beginning or learning to read, their decoding was far from automatized. Time pressure may therefore have influenced their matching attempts.

Nevertheless, the obtained accuracy results confirmed group status as determined at the end of kindergarten, subsequent to the intervention. Children assigned to the high literacy level group (HL) showed higher accuracy than the lower skilled children (LL) in matching pictures to words, and they tended to be more accurate in matching words to picture primes. Either one of these matching conditions required the children to first decode the word in order to decide whether the two stimuli were a match, that is, shared the same connotation, or not. The HL group was also better in detecting word repetition than the LL group, a condition in which pair-wise presented words could be identical or not. The performance on the control condition requiring the detection of repeated pictures was quite similar for both groups, not only with respect to the hit rate but also to the (low) false alarms rate (see Table 4.2), indicating that literacy level seemed not to affect attention or motivation during the experimental session.

For children to score a hit on repeated word trials, it was not necessary to decode the paired words. Some experience with letter recognition to perceive the distinctive shapes and features of the letters in both letter strings would suffice, as already shown by Maurer, Brem, Bucher, and Brandeis (2005). They presented pre-readers with repeated strings, and
obtained comparable rates for hits (around 50%) and few false alarms to repeated words, pseudowords and symbols. In fact, in our study both groups obtained a fairly high number of hits on detecting repeated words as compared to matching words to pictures and vice versa. On the other hand, the improved accuracy for repeated word matching may signal a priming effect for word recognition of identical words. A successful identified homophonic word prime may have contributed to the facilitated recognition of the target word in the repeated word condition.

Whereas group differences in literacy skills were reflected in accuracy of responses to word conditions, this was not the case for speed of responding. On none of the conditions involving words the children with lower literacy skills had slower reaction times than the children with high literacy skills. As a between-group difference in responding to trials comprising identical picture pairs was absent, apparently the groups did not basically differ in general speed of responding. The considerable standard deviations for reaction time in the word conditions seem to disqualify speed as a reliable indicator of overall literacy performance in case of immature reading skills.

In line with the facilitation tendency for achieving higher accuracy in case of picture-primed word recognition, the ERP topography regarding the early, phonological feature processing stage of word recognition, was also influenced by picture-word order. In this specific time window from 280 to 400 ms, assumed to be related to the process of grapheme-to-phoneme conversion (Bentin et al., 1999), a between-group difference in topography appeared to be absent for picture primed words. In contrast, during unprimed word processing there was a topographic difference between higher and lower skilled children as reflected by more anterior (positive) and posterior (negative) located centroids in the HL group. This may suggest that when processing unprimed words the more advanced children were also able to employ a wider network of brain regions in this phase of word recognition than the less advanced LL group. As phonological processing seems to rely on a network of distributed brain regions (Price, 1998) - both anterior and posterior regions are implicated in storage and retrieval of phonological information (Rumsey et al., 1997) - this differential finding for the early phonological phase of unprimed word recognition fits with the more accurate unprimed responses in the HL group as well as with the notion that better word recognition skills are associated with better phonological access. However, consistent with the observed advantage
across the groups in accuracy for picture-primed over unprimed words, priming also affected brain activity in the LL group given the close resemblance between the topographic pattern to picture-primed word recognition during phonological processing for lower and higher skilled children. As described above, this was not the case for the groups’ unprimed topography during the same stage.

In the time windows 280 to 400 ms, and 400 to 560 ms, relevant for phonological processing and accessing the whole-word form (Grainger & Holcomb, 2009), overall, word stimuli elicited broad negative fronto-centrally distributed activation, with positivity elicited at lateral posterior electrodes. But relative to unprimed word processing, the processing of picture-primed words elicited a different distribution. The topographic change induced by pictorial priming reflected left lateralized negative fronto-central activation, with positive activation distributed over occipito-temporoparietal regions and largest in the right hemisphere. Given the subjects’ age, strong (bilateral) engagement of frontal regions to accomplish phonological processing may be considered developmentally appropriate (Shaywitz et al., 2002). Since decoding was restricted to CVC words, we can only speculate as to whether greater left than right activity in anterior regions during picture-primed word processing is suggestive of a shift to phonological coding that is less based on one-by one processing of the smallest units but rather on processing of bigger chunks (Pugh et al., 1997). Nevertheless, based on the altered characteristics of brain activation to picture-primed as opposed to unprimed word processing observed across groups we might assume that priming affected the processes of phonological encoding in early readers with low literacy skills in a similar way as the higher skilled early readers.

Another prominent general effect of pictorial priming at the two stages of phonological (sub)processing also independent of literacy level was the greater map strength observed to picture-primed words relative to unprimed words. The overall activation was even greater for words preceded by congruent picture-primes (bearing the same connotation) as opposed to unrelated picture-primes. Although the relatively long exposure duration of the pictorial primes may have resulted in enhanced activity (Zago, Fenske, Aminoff, & Bar, 2005), a more functional explanation comes from Henson (2003), who suggested that so-called ‘active’ priming may take place “whenever priming causes a new process to occur on the target that did not occur on the prime” (p. 71). Regarding our data, exposure to a highly
recognizable picture may have been sufficient to form a phonological representation that facilitated recognition of the subsequent presented word, but given the substantial difference in larger overall map strength - apparently at the cost of greater activation.

To summarize the behavioural and electrophysiological evidence for the effect of pictorial priming on phonological facilitation, our assumption that priming with pictures would especially affect phonological encoding in children with low phonemic skills was partially supported. Presenting picture-primed words tended to increase recognition accuracy and elicited a shift in topographic distribution, but apparently regardless of literacy level. As a result, the behavioural difference between the more and less advanced literacy groups found for unprimed word recognition was reduced for picture-primed word recognition, whereas the topographic dissimilarity in responding to unprimed stimuli was absent with regard to picture-primed ones.

4.4.2 Effects of pictorial priming on congruency processing

The not quite abridged between-group difference in accuracy outcome for decoding picture-primed words indicates that priming did not entirely close the gap between the two groups of at-risk children. Given the relatively high rate of misses to mixed stimuli pairs it is also clear that the word recognition skills of the low performers were still very rudimentary. This last observation may hold true also for the group with better emergent literacy skills, although they performed with more accuracy. So, the question arises, whether mapping and integration skills of the participating kindergartners were indeed sufficiently developed after 14 hours of training to expect evidence of a priming related congruency effect on brain functioning at the later stage of processing between 560 and 700 ms post-stimulus onset, related to stimulus categorization and stimulus retrieval.

The clear shifts in topographic distribution around 580 ms to primed and unprimed words and observed across groups signalled the start of a different neural process. The relatively low map strength during unprimed word processing indicated that only a neural representation had to be developed, as no match detection was involved as yet (Kok, 2001). For priming per se, thus even though prime and target did not necessarily share the same connotation, enhanced brain activity was accompanied by an anterior negative shift and a posterior positive shift. This observation of heightened activity to all primed word regardless of congruency may seem
puzzling at first. But recall that in order to respond in line with task requirements, the children were tuned to identify certain target features i.e. graphemes corresponding to the phonemes in the picture's name. With attention being focused on identification, non-targets are also known to elicit substantial P3 activity (Kok, 2001). However, if congruency was taken into account, we found subtle divergences in the way neural systems were engaged by the different levelled early readers. Words primed by identical pictures were responded to with greater strength of activation, but to a lesser extent by the group with better literacy skills. Also, target words congruent with the prime induced in those better performing children a different topography compared to words within incongruent picture-word pairs. By contrast, the lower skilled group of early readers did not display such topographic congruency-incongruency differences.

That pictorial priming modulated the later-going GFP component such that analysing congruent trials was marked by more processing activity than conflicting (incongruous) ones is not in line with the recent ERP findings of Andres et al. (2011). Note however that the authors investigated the impact of unattended congruency on the P3 component. In our study, event categorization was directly related to the decision whether the word stimulus did or did not match with the internal representation of the preceding picture. In such a paradigm, matches are known to elicit larger P3s than mismatches (Kok, 2001). However, strength of activation may not only depend on the closeness of the match, but as stated before also on the amount of attention required in processing the target.

Providing no doubt exists about the actual match between prime and word, processing congruency may be considered less difficult. Even so, the groups' greater enhancement on congruent trials seems to suggest otherwise. All children had encountered these trained word stimuli repeatedly over a period of time while participating in the emergent literacy intervention, but as we now know, automatized word recognition is not to be expected in an early stage of learning to read (McCandliss & Noble, 2003). With decoding still a slow and laborious process, integration of orthographic and phonological information may be facilitated by priming as our results seem to indicate, but will not be fast and effortless either. Salient is however that the LI group tended to elicit even greater neural activity to congruent than to incongruent pairs which might be due to having greater difficulty in analysing the occurrence of an actual match and deciding accordingly.
In this particular time window between 560-700 ms, frontal regions are implicated in retrieval of lexical and semantic information from memory (Fiez, 1997; Wagner, Desmond, Demb, Glover, & Gabrieli, 1997). The lower recruitment of frontal resources on congruent trials in the higher skilled group relative to the lower skilled group seems to confirm a reduced need for stimulus analysis processes. The accompanying positive shift in topography in the HL group towards a less posterior, more parietal distribution on congruent trials can be interpreted as adaptive processing and integration of task related information (Peers et al., 2005). Whereas the decreased frontal negativity as shown by the HL group may reflect automatic allocation of attention, a topographic distribution of anterior negativity together with a more posterior positivity is assumed to reflect effortful attentional allocation and stimulus evaluation (Volpe et al., 2007). Such a distribution was found across groups on incongruent trials, but only for the lower skilled group on congruent trials also. The divergence in topographic distribution between congruent and incongruent responding present for the HL group yet absent for the LL group may thus reflect lower attentional demands during the processing of congruency for higher skilled children only.

The observed congruent-incongruent difference in topographic distribution accompanied by a tendency for reduced enhancement in the HL group, might be reconciled with a still immature but developing form of a congruency effect. In contrast, in the absence of a stimulus-driven shift in topography together with a tendency to stronger enhancement no such indications of tuning of attentional and integrative processes as a function of congruency were found for the LL group. Whether this observation points in the direction of a deficient development in integrating phonological and orthographic processes resulting from deviant processing of letters and speech sounds as found for older dyslexic children (Blau et al., 2010) is still too premature to tell. Further investigation of developmental course of word recognition in the context of facilitatory priming including older participants will be necessary. That however the absence of a congruency effect, i.e., enhanced or lack of reduced responding related to integration of congruent information is associated with (familiar risk for) dyslexia has been confirmed in several other studies using different paradigms (Jednorog, Marchewka, Tacikowski, & Grabowska, 2010; Miles & Stelmack, 1994; Pugh et al., 2008; Torkildsen et al., 2007).

Caution about making too strong a statement regarding the literacy-
related behavioural and neurophysiological differences and similarities that were observed in the present study is certainly appropriate given the rather low accuracy scores, the small number of subjects in the study and the limited set of (congruent) picture-word trials. Another weakness of the study is the limited occipital and temporal coverage (no additional channels besides all 32 standard channels of the 10-20 system were included). It is not unlikely that other (small) differences in neural activation might have gone undetected between the more and less skilled early readers. On the other hand, although low and high responders could be differentiated on behavioural measures following the intervention, the (pre)literacy skills of low responders also improved. So lack of significant correlations between the neurophysiological and behavioural measures may also be partly due to the small topographic subgroup differences and the beneficial effect of intervention on phonological processing in all participants. Recently it was reported that minor topographically differences between poor and normal readers in N1 print sensitivity (contrast between words and false fonts) found prior to an early literacy training that was similar to ours in content and developmental period had disappeared with training (Brem et al., 2013).

Despite the current limitations, our study shows that a word-picture priming paradigm to facilitate integration of phonological and orthographic information offers an interesting approach to identify behavioural and neurophysiological characteristics which may mark the beginning of differential trajectories in reading development at kindergarten age. Within a specific at-risk group of very early readers all with a familial history of dyslexia, all recipients of an emergent literacy intervention, one group of children clearly failed to benefit as much from the structured training in (pre-)literacy skills as the other group. The lower response to intervention could be verified by atypical neurophysiological functioning. Follow-up on these children will determine if the accumulation of risk factors indeed predisposes to development of reading problems.

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