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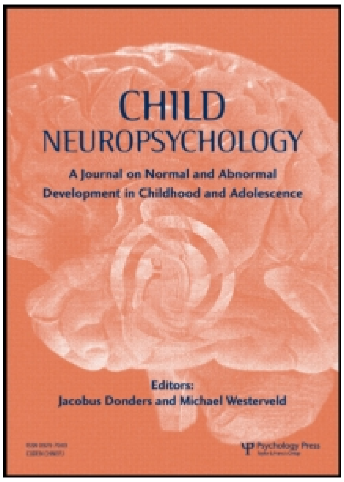

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Verbal and Affective Laterality Effects in P-Dyslexic, L-Dyslexic and Normal Children*

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ABSTRACT

Lateralization of verbal and affective processes was investigated in P-dyslexic, L-dyslexic and normal children with the aid of a dichotic listening task. The children were asked to detect either the presence of a specific target word or of words spoken in a specific emotional tone of voice. The number of correct responses and reaction time were recorded. For monitoring words, an overall right ear advantage was obtained. However, further tests showed no significant ear advantage for P-types, and a right ear advantage for L-types and controls. For emotions, an overall left ear advantage was obtained that was less robust than the word-effect. The results of the word task are in support of previous findings concerning differences between P- and L-dyslexics in verbal processing according to the balance model of dyslexia. However, dyslexic children do not differ from controls on processing of emotional prosody although certain task variables may have affected this result.

Samuel Orton, who in the 1920s pioneered the search for hemisphere-specific factors underlying cognitive deficits, theorized that reading disability or dyslexia may arise from the failure of one side of the brain to ‘‘dominate’’ the other side (Orton, 1966). According to Satz and Sparrow (1970): ‘The disorder of reading may, in large part, be due to a lag in the maturation of the left hemisphere and a corresponding lag in the functional specialization of language’.

To determine hemispheric specialization of function, behavioral methods are employed which include auditory, visual, and haptic stimulation techniques to demonstrate perceptual asymmetries, and measures of hand preference or performance as indices of motoric asymmetry. The dichotic listening technique, constituting a behavior measure to examine perceptual asymmetries, enables the exploration of lateralization of language processes in dyslexic and normal children. In the conventional dichotic listening situation, series of different auditory stimuli are presented to the two ears simultaneously. Kimura’s (1967) structural model of dichotic listening performance suggests that the ipsilateral pathways are blocked by activity in the stronger contralateral pathways, with the result that left ear information is first processed in the right cerebral hemisphere, while right ear information is initially processed in the left cerebral hemisphere. In normal children, one finds a right ear advantage for the identification of verbal stimuli such as words, digits and CV syllables, and a left ear advantage for the identification of various types of non-verbal material, such as music, environmental sounds, or emotional material (Bryden & Bulman-Fleming, 1994).

Free recall studies using either three to four pairs of digits or CV syllable pairs (ba, da, pa and ka), showed a right-ear advantage for normals and varying right- and left-ear advantages in dyslexics (Sparrow & Satz, 1970; Zurif & Carson, 1970; Witelson & Rabinovitch, 1972;

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McKeever & Van Deventer, 1975; Yeni-Komshian, Isenberg & Goldstein, 1975; Mercure & Warren, 1978; Brunswick & Rippon, 1994). Studies employing a ‘‘ three mode response strategy’’ (free recall, directed attention to the right and directed attention to the left) with pairs of CV or CVC syllables showed that normals had a right-ear advantage in all conditions and learning disabled had a right-ear advantage in the free recall and directed right condition with a trend towards a left-ear advantage in the directed left condition (Boliek, Obrzut & Shaw, 1988: Obrzut, Conrad, Bryden, & Boliek, 1988). Kershner and Morton (1990) employing pairs of digits found that when attention was directed to the right ear, learning disabled had a greater right-ear advantage compared to normals, but when attention was directed to the left ear the learning disabled had a reduced right-ear advantage compared to normals. These results are consistent with the view that learning disabled children do not suffer from a fixed laterality deficit, but that a task dependent attentional dysfunction may interfere with left hemisphere language processing. Thus, these studies provide inconsistent results in differentiating dyslexics from normal readers according to ear advantage.

Dyslexia Subtypes and Hemispheric Asymmetry of Language Processes

Although the hypothesized attentional dysfunction may partly explain the inconsistent findings in ear advantage in dyslexic children, another important factor concerns the existence of subtypes of dyslexia. Hooper and Willis (1989) extensively address this topic from a neuropsychological point of view and conclude that generally three subtypes show up that are characterized by language deficits, visuo-spatial deficits or a combination of these deficits. Two of these subtypes have been extensively studied in our laboratory.

The balance model of dyslexia

According to Bakker’s (1981) developmental model for reading acquisition, visuo-perceptual and syntactic-semantic analyses are prominent in initial and advanced reading, respectively. In initial reading all script is uncommon; it is perceptually complex; and reading is slow. It is assumed that the reading of uncommon/novel script activates the right hemisphere (Goldberg & Costa, 1981). After some reading experience, initial reading becomes advanced reading. It is assumed that the left hemisphere is activated in the reading of common/familiar script (Goldberg & Costa, 1981). This view implies that at some point during the learning to read process, a right-left change in hemispheric mediation of reading takes place. According to the balance model of dyslexia (Bakker, 1981), some children may not be able to switch from right to left hemisphere mediated reading strategies. They have been classified as P-type (P of perceptual) dyslexics; P-dyslexics are slow but accurate readers. On the other hand, there may be beginning readers who overlook the visuo-spatial challenges of the text. They have been labeled L-type (L of linguistic) dyslexics; L-dyslexics are fast, inaccurate readers. With respect to ear advantage it has been reported that L-types tend to show a right ear advantage, whereas P-types show a lack or a left-ear advantage in dichotic free-recall tasks using three to four digit pairs as the stimulus material (Bakker, Licht, Kok & Bouma, 1980; Bakker & Vinke, 1985). These findings were replicated in a later study by Masutto, Bravar & Fabbro (1994). Obrzut, Obrzut, Bryden, and Bartels (1985) found that normals had a right-ear advantage in a free recall, and an attend-right and an attend-left condition using CV syllables as stimuli. However, auditory-linguistic disabled readers, who are comparable with P-dyslexics, had a right-ear advantage in the free-recall and attend-right condition, but a left ear advantage when attending to the left dichotic channel (influenced by attentional instruction). Generally, the learning disabled children showed a reduced right ear advantage in all conditions compared to the normals. Morton (1994) identified certain groups of learning disabled children on the basis of word-recognition, word-attack, or reading comprehension. It is assumed that a word-recognition problem may be logically linked to right hemisphere dysfunction, and a word-attack problem to left hemisphere dysfunction (Bakker, 1982; Beaton, 1985). Using a directed-attention task employing CV pairs Morton found that reading disabled subjects with a reading comprehension problem but no word-attack problem had a greater right-ear advantage-left hemisphere engagement, whereas subjects with a word-attack problem and comprehension problems but no word-recognition problems showed a greater left-ear advantage-right hemisphere engagement. These findings are in accordance with those reported by Bakker (1982) for L- and P-dyslexics. In a single response dichotic listening study conducted by Hughdahl, Helland, Faerevaag and Lyssand (1995), dyslexic subjects were presented with CV syllable pairs. It was found that subjects with a type of dyslexia similar to P-types did not show the expected right ear advantage as normal readers did. In summary, these studies seem to indicate that more consistent results can be obtained in ear advantage pattern when dyslexics subjects are classified according to type of dyslexia such as P-dyslexic or L-dyslexic children.

Internal and External Validity of the Dichotic Listening Test

In ‘classical’ dichotic listening studies free recall measures (subjects had to report all that they could remember) and 3 to 4 pairs of digits were administered to assess language lateralization in dyslexic (subtypes) and normal children. Two important issues should be addressed, concerning the internal and external validity of the procedures followed in the ‘classical’ dichotic listening test. Regarding the internal validity, the first problem is that subjects may choose to deploy their attention in a variety of different ways with the general instruction to ‘‘report all that you can remember’’ (Bryden, 1982), and this will have an effect on the observed laterality effect. A second problem is that subjects vary in report strategy. So recall strategies (order-of-report strategies) also have an effect on observed laterality. A third problem is that by offering 3 to 4 pairs of digits, subjects would have to rehearse the items before recalling them; one would therefore be measuring short-term memory instead of perceptual laterality effects. In summary, problems with the above mentioned procedures in dichotic listening studies are that attentional biases, recall strategies, and short-term memory factors could have influenced the observed laterality effect (Bryden, 1978). Thus, the internal validity for the diagnostic use of the ‘classical’ dichotic listening procedures as indices of hemisphere specialization for language perception still remains questionable. According to Hughdahl (1995) memory effects can be handled by having the subjects report only on one stimulus on each trial (instead of double answers). Order of report effects and attention can be controlled for by having subjects reporting only from the right ear or left ear (directed attention dichotic listening task). And finally, in studies employing a three-mode response strategy, attention may be separated out by comparing ear advantage effects across the three report conditions. Thus, the dichotic listening task seems to be internally valid in a directed attention task, a three-mode response strategy task or by having subjects give single answers.

Regarding its external validity, the dichotic listening test seems to be a valid measure of cerebral dominance for central auditory and language related functions as evidenced by studies with neurological patients, epileptic patients and split brain patients using sodium-amytal testing procedures (Kimura, 1967; Sperry, 1968; Hughdahl, Carlsson, Uvebrant & Lundervold, 1997). Electrophysiological validation of ear advantages, by measuring electrical brain activity during dichotic listening tasks, have been reported by Bakker, Licht, Kok and Bouma (1980) for children with a consistent REA or LEA who showed opposite asymmetries for amplitude and latency of a late negative ERP component elicited by words. Van den Vijver, Kok, Bakker, and Bouma (1984) found a lateralized sustained positive wave at temporal sites during rehearsal of the dichotic stimulus material, whereas Ahonniska, Cantell, Tolvanen and Lyytinen (1993) reported Ear Advantage-related asymmetries of the P300 component at temporal sites using CV stimulus pairs. In conclusion, these findings support the notion that Right and Left Ear Advantages are determined, at least in part, by hemispheric side of language mediation.

Dyslexia and Hemispheric Mediation of Affective Processes

Hemispheric mediation of nonverbal (emotional) stimuli

One of the goals of the present study was to examine whether (subtyped) dyslexic children have different patterns of lateralization of prosody from normal readers as measured with the dichotic listening technique. The literature-search revealed studies neither on the lateralization of affective processes in dyslexic (subtyped) children employing the dichotic listening technique, nor on the lateralization of nonverbal emotional sounds in normal children; however, in adults a significant left ear superiority was found with hummed melodic patterns and vocal non-speech sounds such as laughing, crying, sighing, etc. (King & Kimura, 1972), whereas Bryden, Ley and Sugarman (1982) reported that a left-ear advantage was obtained for identifying the emotional quality of tonal sequences in adults.

According to Saxby and Bryden (1984), research on hemispheric asymmetries in normal children suggest that if emotion is cerebrally lateralized, it would be represented in that hemisphere known to be specialized in children for other types of nonverbal processing. Children between 6 and 12 years of age retained Morse-like sound patterns better when presented to the left ear than when presented to the right ear, but series of digits were not retained better via the right ear than via the left ear (Bakker, 1967). Knox and Kimura (1970) showed that children as early as five years of age could correctly identify more nonverbal environmental sounds from the left ear than from the right ear. In contrast, a number of verbal tasks reproduced a right ear superiority for the perception of speech sounds. According to Smith and Griffiths (1987), dyslexic children also showed a normal, left ear perceptual advantage for nonverbal environmental sounds. So it is possible that the right hemisphere advantage for processing various types of nonverbal material found in normal and dyslexic children could extend to include mediation of emotional stimuli (as in adults), which are also nonverbal in nature.

Hemispheric mediation of verbal emotional stimuli

One of the most compelling experiments on the lateral processing of emotional features was conducted by Ley and Bryden (1982), employing verbal emotional stimuli and adults as subjects. Emotionally toned sentences (happy, sad, angry, and neutral voices) were dichotically paired with monotone sentences. A left ear advantage was found for recognizing emotional intonation, while a simultaneous right ear advantage was found for recognizing the verbal content of the sentences.

A replication of the original Ley and Bryden (1982) study on lateralization of verbal emotional processing in normal children of different age groups (Saxby & Bryden, 1984) showed a left ear advantage for reporting on the emotional material, and a right ear advantage for reporting on the verbal material. For the emotional task, the degree of ear asymmetry did not vary significantly as a function of emotional category. These findings indicate that even in 5- and 6-year-olds, judgements of affect lead to a highly significant left ear advantage. This would suggest that right hemisphere mechanisms for the recognition of affect are active even in young children, and, if compared with adults, do not seem to alter significantly with age.

Herrero and Hillix (1990) investigated hemispheric processing of affective speech components within the dichotic paradigm in adults. A spoken sentence, constant in semantic content but varying in mad, sad, and glad emotional tones, was presented to 45 male and 45 female college students. More correct identifications of prosody were made with the left ear than with the right. In several dichotic listening studies (Bryden & MacRae, 1989; Bryden, Free, Gagne, & Groff, 1991; Bulman-Fleming & Bryden, 1994) adults or undergraduates were given two-syllable words (power, bower, dower and tower) differing only in initial stop consonants and spoken in different emotional tones. The stimulus words were paired dichotically, resulting in 72 pairs of word-affect combinations. Subjects were instructed to detect either the presence of a specific word or of a specific emotion (stimulus-detection task with divided attention). When the target was a word, a strong right ear advantage was obtained. When subjects were instructed to indicate the presence of a specific emotion, a left ear advantage was obtained. The data did not provide support for the view that emotionally negative material would produce larger right hemisphere effects than emotionally positive material: all affects showed a left ear advantage, and those for positive (happy) and negative (sad, angry) emotions were of similar magnitude. In conclusion, these studies show that children and adults have a left ear advantage in identifying prosody.

The Present Study

The first goal of the present study was to investigate whether there are hemispheric differences between P- and L-type dyslexic children in processing auditory verbal material using the monitoring task developed by Bryden and MacRae (1989). The second goal of the present study was to investigate lateralization of the processing of prosody in P- and L-type dyslexic children. P- and L-type dyslexic children have a problem in mediation of verbal material (Bakker et al., 1980; Bakker & Vinke, 1985; Masutto et al., 1994; Morton, 1994; Obrzut et al., 1985; Hughdahl et al., 1995). There is no evidence based on the fact that P- and L-type dyslexic children have a problem in mediation of affective material. If one could infer that in normal and dyslexic children nonverbal materials like environmental sounds and melodic patterns are processed by the right hemisphere (Bakker, 1967; Knox & Kimura, 1970; Smith & Griffiths, 1987) then affective processes which are nonverbal in nature should also be mediated by the right hemisphere as in adults (King & Kimura, 1972; Bryden, Ley, & Sugarman, 1982). In normal children and adults a left ear advantage has been found for reporting on the emotional content of a sentence or word (Saxby & Bryden, 1984; Ley & Bryden, 1982; Bryden et al., 1991; Bulman-Fleming & Bryden, 1994). Thus, the second goal was to find out whether the same effect could also be found in P- and L-type dyslexics.

For the above purposes, the Bryden and MacRae (1989) dichotic listening paradigm was used but the stimulus material consisted of four Dutch two-syllable words beren (bears), peren (pears), meren (lakes) and veren (feathers) spoken in a happy, sad, angry and neutral tone of voice, differing only in the initial stop consonant. The children had to detect in one set of trials a specific target word and in a second set of trials a specific target emotion, while monitoring both ears. This stimulus detection task with pairs of word-affect combinations was used because it was expected that the effects can be attributed to hemispheric specialization of perception with greater certainty than in the ‘classical’ dichotic listening test (Bryden, Munhall, & Allard, 1983) since the contribution of recall strategies and short-term memory to the experimental effects are reduced (Bryden, 1978).

It was expected that P-dyslexics would show a left ear advantage or lack of ear advantage in the verbal condition and that L-dyslexics would show a right ear advantage, similar to the ear advantages found in studies reported by Bakker et al. (1980), Bakker and Vinke (1985), Masutto et al. (1994), Obrzut et al. (1985), and Hughdahl et al. (1995). Normal children, as a comparison group, would have a right ear advantage (Zurif & Carson, 1970; Witelson & Rabinovitch, 1972; Saxby & Bryden, 1984). Since it is assumed that dyslexia is primarily characterized by deficits in the verbal domain (World Federation of Neurology, 1968) it was expected that in the emotion condition P- and L-type dyslexic children would show similar patterns of left ear advantages like normal children and adults (Saxby & Bryden, 1984; Ley & Bryden, 1982; Bryden et al., 1991; Bulman-Fleming & Bryden, 1994).

METHOD

Subjects

From a special school for children with learning disabilities in Amsterdam a group of 53 right-handed children (40 boys and 13 girls aged 9 to 12) were selected who, despite conventional instruction, socio-cultural opportunity, average intelligence, and freedom from gross sensory, emotional or neurological handicaps, failed to acquire normal reading proficiency (World Federation of Neurology, 1968). The group was first subjected to a Dutch one-minute word reading task that consists of a list of words that gradually increase in difficulty (OMT; Brus & Voeten, 1973). The number of words read correctly in one minute was scored. Thereafter, the one-minute test score was transformed into a DAE score (didactic age equivalent) indicating the didactic age corresponding with the reading level. On the basis of the DAE score on the OMT a certain level of the Dutch sentence reading task (AVI; Van den Berg & Te Lintelo, 1977) was administered. The AVI consists of nine levels of text complexity that corresponds with different reading levels. Subsequently, the children's reading level for text reading (mastery level) was determined by scoring the number of reading errors and reading time. For each child the DA score was computed (didactic age) with one year of education being equivalent to a DA of ten months. The results showed that 40 of the children (32 boys and 8 girls) had a lag in reading ability of at least one and a half years (the difference between DA and DAE on the OMT had to be at least 15 months). These children fulfilled our criteria for being dyslexic and subsequently participated in the present study.

Classification of dyslexics in L- and P-types
These 40 children were subjected to the AVI sentence reading task, two levels above their mastery level in order to evoke reading errors. The performances on the AVI stories were recorded on a tape. This was done to classify L- and P-dyslexic children according to speed and accuracy of reading. The time required for the sentence reading task, and number of substantive and time-consuming errors were noted. Substantive errors include omissions and additions of letters and words, word mutilations, and all other ''real'' mistakes. Time-consuming errors are not really errors at all but instead involve words that are initially read in a fragmented (spelling-like) and/or repetitive fashion, but are eventually read correctly (Bakker, 1990). If, according to a classification based on the study by Spyer (1994), the reading time of the child divided by the standard AVI reading time was less than 125 (time child/time AVI in seconds × 100), and 55% or more of the reading errors were substantive (substantive errors/total errors × 100), the child was classified as a L-dyslexic (fast, inaccurate reader). If, however, the reading time of the child divided by the standard AVI reading time was larger than 125 (time child/time AVI in seconds × 100), and 55% or more of the reading errors were time-consuming (time-consuming errors/total errors × 100), the child was classified as a P-dyslexic (slow, accurate reader). This procedure correctly classified 33 children (27 boys and 6 girls) into 19 L-dyslexics and 14 P-dyslexics.

Control children
The control group was formed by 20 children aged 9 to 12, with normal reading ability at a primary school in Amsterdam. These children were right-handed boys with normal intelligence. This control group did not present any reading or learning disorders. In total, 19 L-dyslexics, 14 P-dyslexics, and 20 normal children were administered the dichotic listening test.

Table 1 shows a number of subject variables (e.g., total number of children, sex, age, reading performance, reading errors, didactic age and the didactic age equivalent) for L-, P-dyslexics and control group children. It is clear from Table 1 that L-dyslexics have a short reading time and make relatively many substantive errors, and that P-dyslexics have a long reading time and make relatively many time-consuming errors (Spyer, 1994).

Stimulus Material
Four different two-syllable Dutch words (veren, beren, peren and meren) were spoken by a female speech therapist in four different affective tones (happy, angry, sad and neutral) and recorded on a DAT tape in a professional studio setting. This provided a total of 4 × 4 = 16 stimulus items, which were digitized on a computer. The stimuli were edited in such a way that signal length and loudness was in the same range for all stimuli.

Pilot study
After recording 2 × 16 = 32 of the stimuli in random order on a tape with 5 second inter-stimulus intervals, 20 adults rated these stimuli on affective tone. The results showed that 76.67% of the first three word-affect combinations were correctly identified, and that 99.14% of the last 29 word-affect combination were correctly identified. From these pilot findings one may conclude that in the beginning the adults had to get used to the stimuli, and that performance was best after the first three word-affect combinations. In total 97.03% of the trials were correctly classified. It was assumed that if adults could correctly identify the affective tone of the tokens so could children.

Table 1. Total Number of Children, Number of Boys and Girls and Mean Age (in Months) for L- and P-Dyslexics and Control Group Children (C-Children). In Addition, Mean and Standard Deviations (Between Parentheses) of the AVI-Mastery Level (AVIB), AVI-Reading Time (AVIR), AVI Substantive Errors (AVIS), AVI Time-Consuming Errors (AVIT), Didactic Age (DA) and Didactic Age Equivalent (DAE) Are Depicted for L- and P-Dyslexics.

Variables	L-dyslexic		P-dyslexic		C-children	Total
	M	(*SD*)	*M*	(*SD*)		
Total (N)	19		14		20	53
Boys (N)	16		11		20	47
Girls (N)	3		3		0	6
Mean age	137.42		124.57		130.45	130.81
Mean-AVIB	3.79	(2.20)	2.00	(1.47)	–	–
Mean-AVIR	82.95	(23.23)	159.43	(30.15)	–	–
Mean-AVIS	11.63	(4.49)	8.14	(3.16)	–	–
Mean-AVIT	4.53	(2.29)	16.64	(7.33)	–	–
Mean-DA	42.42	(8.98)	32.57	(8.64)	–	–
Mean-DAE	20.00	(7.22)	10.36	(4.99)	–	–

The dichotic listening test

To construct the dichotic listening test each word-affect combination was paired with every other word-affect combination that differed in both affective tone and verbal content, to produce 16 × 9 = 144 different pairs of stimuli. The pairs of stimuli were presented to the subject using ERTS (Experimental Run Time System; Beringer, 1996) which is a programming language for building psychological experiments. The stimuli were presented to the subjects using a sound-blaster card (Creative Labs, 16 bits). These word-affect combinations were presented through a headphone attached to the computer with normal speech loudness. There was a 4-second inter-stimulus interval between the presentation of consecutive stimulus pairs with a stimulus-pair duration of 800 milliseconds, and a 15-second pause after each group of 48 trials. Prior to the actual dichotic listening test 20 practice trials were administered.

Procedure

The dyslexic children were randomly divided into four groups, each consisting of P- and L-type dyslexics. Group 1 consisted of 8 children (7 boys and 1 girl; 4 L-dyslexics and 4 P-dyslexics), group 2 of 8 children (5 boys and 3 girls; 5 L-dyslexics and 3 P-dyslexics), group 3 of 8 children (6 boys and 2 girls; 5 L-dyslexics and 3 P-dyslexics) and group 4 of 9 children (9 boys; 5 L-dyslexics and 4 P-dyslexics). The control children were also divided into four groups each consisting of 5 subjects, but each group was matched according to the average age level in the dyslexic groups. Each group had as their targets a different word and a different affect: veren-happy (group 1), beren-angry (group 2), peren-sad (group 3) and meren-neutral (group 4). In one set of trials (Verbal Condition), the subject was instructed to monitor for a pre-specified target word (e.g. veren), and to indicate whether or not that word occurred in the dichotic pair. In a second set of trials (Emotion Condition), the subject was told to listen for a particular emotional tone (e.g. happy), and to indicate whether or not that particular emotion had been presented. Each participant was tested individually in a room at the school. In each dichotic session, the participant was first told what dichotic listening consisted of, what his or her target item was, and how to respond.

Verbal condition

First the children heard 20 word-affect combinations through a headphone connected to the computer and had to respond with their right hand: mouse-button right meant ‘‘yes’’, the target was present; and mouse-button left meant ‘‘no’’, the target was not present. While performing the task the children had to look at a fixation point in the middle of the screen. After these 20 practice trials, the actual test started where the children heard 144 word-affect combinations and had to respond to their target word.

Emotion condition

The children heard 20 word-affect practice combinations and had to respond ‘‘mouse-button right’’ if their target affect was present, and ‘‘mouse-button left’’ if their target affect was not present. Also here, the children had to look at a fixation point during the presentation of the stimuli. Thereafter, the actual test was commenced with the children responding to 144 word-affect combinations.

Any target, a word or an emotion, was registered 36 times each on the left and right ears; 72 times there was no verbal or emotional target. The computer registered reaction times from the onset of the stimuli and accuracy of responses on left and right ear presentations. It was decided to employ a fixed order of presenting the verbal condition first and thereafter the emotion condition. This was done because the pilot study showed the verbal condition to be easier than the emotion condition. By presenting the verbal condition first less interference was expected with the emotion condition than when this order would be reversed.

Data Analysis

Analysis of verbal and emotion conditions

Separate overall ANOVAs with repeated measures were performed on reaction time and accuracy measures respectively, with Task (verbal vs. emotional) and Ear (left vs. right) as within-subject factors and Group (P-dyslexic vs. L-dyslexic vs. Controls) as a between-subject factor. In case of significant Task by Ear interactions further analyses of ear differences were performed per task. In all analyses reaction times were calculated for correct responses only.

In order to check for confounding gender-related effects in the ANOVAs, all analyses were also performed on boys only. Since there were no substantial differences in effects between analyses on all children or boys only, we decided to report those results that are based on the largest number of subjects (boys and girls).

Explorative analysis of word categories and emotional categories

To test whether word categories have a differential effect on ear advantage, different analyses of variance were done. It was assumed that ‘veren’ and ‘meren’ would be detected faster/more accurately than ‘beren’ and ‘peren’. The ‘v’ and ‘m’ consonants differ in place of articulation and are relatively easy to discern from the other initial consonants. In contrast, the ‘b’ and ‘p’ consonants differ in voice onset time (VOT) and it was expected that particularly the dyslexics would have difficulties discerning these stop consonants. Group (dyslexics vs. controls) and Word-category (children with ‘veren’, ‘meren’, ‘beren’ or ‘peren’ as target words) were the between-subject factors and Ear (right ear, left ear) was the within-subject factor.

To test whether certain emotions have a differential effect on ear advantage an analysis of variance was done for the emotions happy, angry, sad and neutral. The between-subject factors were Group (dyslexics vs. controls) and Emotion-task (happy, angry, sad and neutral), whereas Ear was the within-subject factor (right ear, left ear). *P*-values = 0.05 were considered statistically significant in all tests.

RESULTS

Analysis of Verbal and Emotion Conditions

Reaction time

Table 2 depicts mean reaction times in the Word and Emotion task for L-, P- and control group children.

Analyses of reaction times showed that responses were generally faster in the Word than in the Emotion task (F(1,50) = 38.5, *p* = .001,

Table 2. Mean Reaction Times and Standard Deviations for Right and Left Ear Targets in the Word and Emotion Task for L- and P-Dyslexics and Control Group Children.

Group	*N*	WORD				EMOTION			
		Right ear		Left ear		Right ear		Left ear	
		M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
L-dyslexic	19	1253.76	(309)	1399.35	(368)	1582.91	(436)	1541.38	(409)
P-dyslexic	14	1555.01	(321)	1689.73	(451)	1930.56	(343)	1820.86	(418)
C-children	20	1405.77	(364)	1549.60	(346)	1817.41	(449)	1738.18	(422)
Average	53	1390.70	(348)	1532.75	(393)	1763.23	(435)	1689.47	(425)

eta = 0.44), and that L-type children were faster than P-type children but did not differ from controls (F(1,50) = 3.28, *p* = .046, eta = 0.12). The interaction Task × Ear was significant (F(1,50) = 34.3, *p* = .001, eta = 0.41). Further analysis per Task revealed a significant Right Ear Advantage in the word task (F(1,50) = 23.6, *p* = .001, eta = 0.32) and a signficant Left Ear Advantage in the emotion task (F(1,50) = 9.5, *p* = .003, eta = 0.16).

See Figure 1 for an illustration of Task by Ear effects on reaction time.

Accuracy

Table 3 shows the mean accuracy in the Word and Emotion task for L-, P- and control group children. Analyses of the number of correct responses showed that target words were generally detected more accurately than target emotions (F(1,50) = 34.6, *p* = .001, eta = 0.41). The interaction Task by Ear appeared to be significant (F(1,50) = 36.8, *p* = .001, eta = 0.42). Further analyses showed that words were perceived more accurately when presented to the right rather than to the left ear (F(1,50) = 26.9, *p* = .001, eta = 0.35), and emotional stimuli more accurately when presented to the left rather than to the right ear (F(1,50) = 10.3, *p* = .002, eta = 0.17). This analysis also revealed a significant interaction Group by Ear (F(1,50) = 3.7, *p* = .042, eta = 0.12) in the word task, indicating that L-type children differed from P-type children in Ear Advantage: L-types were significantly more accurate with the right than with the left ear (*p* = .001), whereas P-types did not show significant differences (*p* = .300). This interaction is depicted in Figure 2.

Explorative Analysis of Word and Emotion Categories

Analysis of Word-category effects

For reaction time measurements no significant Word-category or interaction effects were found (see Table 4 for average reaction time and accuracy for each of the Word categories). Generally, right ear responses appeared to be faster than left ear responses (F(1,45) = 25.70, *p* = .001, eta = 0.36). Only the interaction of Word-category by Ear tended to be significant (F(3,45) = 2.33, *p* = .087, eta = 0.13). Further tests showed that both word categories 'peren' and 'meren' were associated with significantly faster responses with the right than with the left ear (*p*

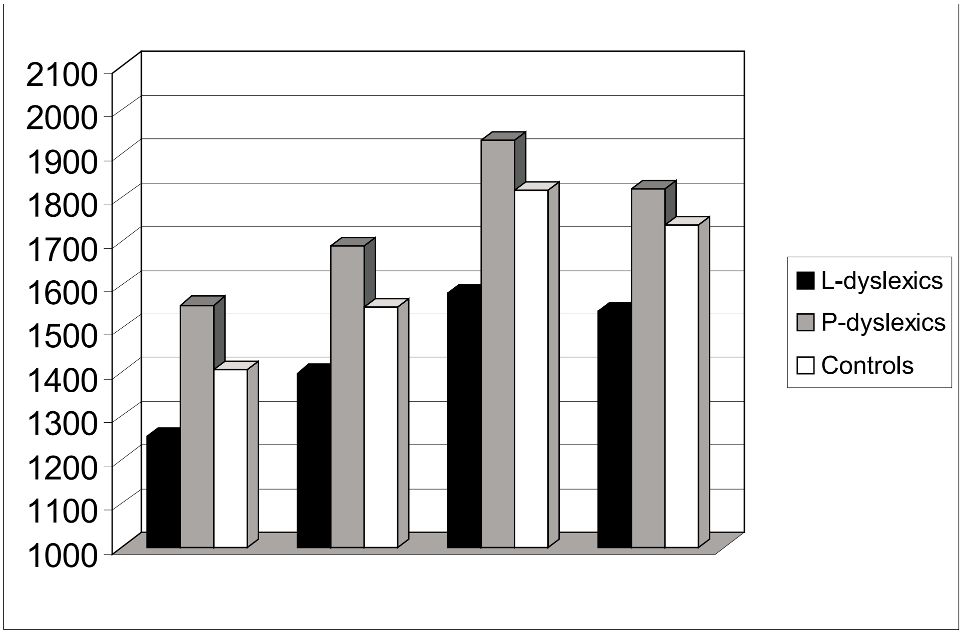

Fig. 1. Mean reaction time and SD (in msec) for word and emotion targets presented to the right and left ear.

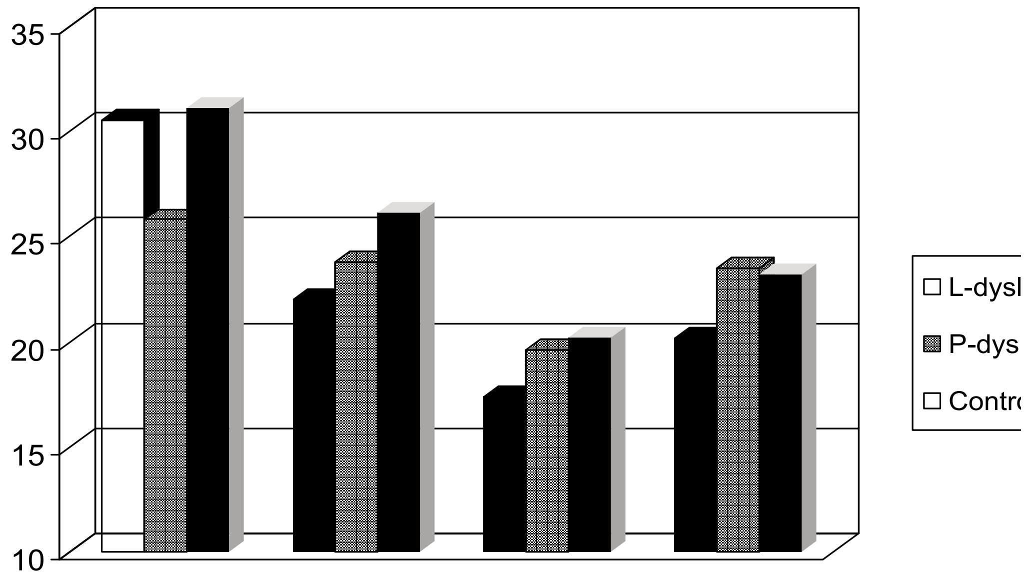

Fig. 2. Mean accuracy and SD (number correct) for word and emotion targets presented to the right and left ear.

= .021 and *p* = .001 respectively), whereas no significant ear differences for 'beren' and 'veren' were found.

Analysis of response accuracy for word categories only revealed that overall right ear performance was more accurate than left ear performance (F(1,45) = 22.69, *p* = .001, eta = 0.34), and that control children generally performed better than dyslexics (F(1,45) = 4.04, *p* = .050, eta = 0.08).

Analysis of Emotion-category effects

Analysis of reaction times showed that responses were generally faster on items presented to the left than to the right ear (F(1,45) = 10.57, *p* = .002, eta = 0.19). The interaction Group by Emotion by Ear was significant (F(3,45) = 3.80, *p* = .016, eta = 0.20). Further tests per group showed a significant interaction Emotion by Ear (F(3,16) = 3.61, *p* = .036, eta = 0.40) for control children only. The latter interaction indicates that significant Ear differences (L-ear faster than R-ear) existed in the neutral condition only (*p* =

Table 3. Mean Number of Correct Responses and Standard Deviations for Right and Left Ear Targets in the Word and Emotion Task for L- and P-Dyslexics and Control Group Children.

Group	*N*	WORD				EMOTION			
		Right ear		Left ear		Right ear		Left ear	
		M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
L-dyslexic	19	30.53	(5.4)	22.00	(7.9)	17.42	(5.5)	20.16	(6.4)
P-dyslexic	14	25.79	(8.2)	23.79	(6.9)	19.57	(8.0)	23.50	(4.8)
C-children	20	31.15	(4.8)	26.10	(5.6)	20.15	(7.0)	23.15	(6.5)
Average	53	29.51	(6.4)	24.02	(6.9)	19.02	(6.8)	22.17	(6.2)

Table 4. Mean Reaction Times and Accuracy for Right and Left Ear Targets in Each Word-Category Group (Veren, Meren, Beren and Peren) Averaged across L- and P-Dyslexics and Control Group Children (Standard Deviations Between Parentheses).

Group	*N*	RT				Accuracy			
		Right Ear		Left Ear		Right Ear		Left Ear	
		M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Veren	13	1374.39	(399)	1431.50	(381)	27.15	(8.0)	22.15	(8.6)
Meren	14	1384.02	(276)	1636.17	(364)	31.43	(7.3)	25.50	(6.6)
Peren	13	1354.52	(400)	1526.56	(454)	28.92	(5.1)	24.46	(6.4)
Beren	13	1450.35	(346)	1528.80	(390)	30.38	(4.2)	23.85	(6.3)
Average	53	1390.75	(349)	1530.76	(394)	29.51	(7.4)	24.02	(6.9)

.013). Table 5 depicts the average reaction time and response accuracy for dyslexics and controls in the four different emotion conditions.

Analysis of accuracy measures revealed a main effect of Ear (F(1,45) = 11.9, p = .001, eta = 0.21), showing that responses with the left ear were generally more accurate than responses with the right ear, across emotions. Also a significant Group by Emotion by Ear interaction (F(3,45) = 3.09, p = .036, eta = 0.17) was found. This interaction is depicted in Figure 3. Further testing per group showed an Emotion by Ear interaction (F(1,29) = 7.8, p = .001, eta = 0.45) only for dyslexic children, indicating that sad stimuli were associated with significantly higher accuracy with the left than with the right ear (p = .004).

DISCUSSION

Findings Related to the Primary Purposes of the Present Study

The primary purpose of this study was to investigate whether there are functional hemispheric differences between P- and L-type dyslexic children during dichotic processing of (a) the verbal content of stimulus words and (b) during the processing of the emotional intonation of the same stimulus words. It was expected on the basis of earlier studies that for the verbal condition, P-dyslexics would have a lack of ear advantage or even a left ear advantage, and that L-dyslexics would show a right ear advantage. It was further expected that normal children as a comparison group would show a right ear advantage (Zurif & Carson, 1970; Witelson &

Table 5. Average Reaction Times and Accuracy on Right and Left Ear Targets for Happy, Angry, Sad and Neutral Emotion Categories Averaged across L- and P-Dyslexics and Control Group Children (Standard Deviations Between Parentheses).

Group	*N*	RT				Accuracy			
		Right Ear		Left Ear		Right Ear		Left Ear	
		M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Happy	13	1804.48	(497)	1676.57	(443)	19.31	(6.3)	20.69	(4.8)
Angry	13	1617.38	(436)	1606.90	(418)	17.38	(6.8)	19.38	(5.2)
Sad	13	1685.31	(411)	1590.97	(408)	18.46	(7.5)	26.15	(4.6)
Neutral	14	1932.74	(373)	1869.60	(419)	20.79	(6.8)	22.42	(7.7)
Average	53	1763.24	(436)	1689.47	(425)	19.01	(6.8)	22.17	(6.2)

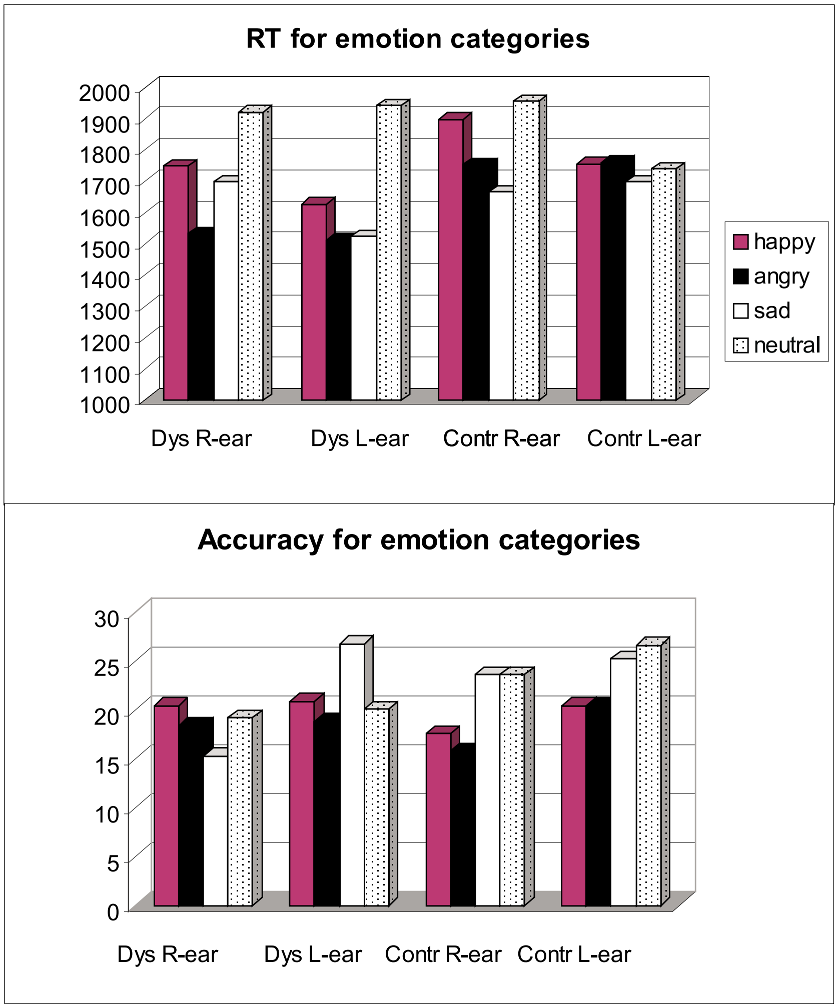

Fig. 3. Mean reaction time (top) and accuracy (bottom) for happy, angry, sad and neutral targets at the right and left ear for dyslexics and controls.

Rabinovitch, 1972; Saxby & Bryden, 1984). For the emotion condition it was expected that both P- and L-type dyslexic children would show a left ear advantage just like normal children and adults (Saxby & Bryden, 1984; Ley & Bryden, 1982; Bryden, Free, Gagne, & Groff, 1991; Bulman-Fleming & Bryden, 1994).

Analyses of reaction time and accuracy measures in both tasks revealed the following results: across groups a significant Right Ear Advantage (REA) in both reaction time and accuracy measures was found for the Word task, except for P-types who showed a lack of ear asymmetry on accuracy.

In the Emotion task a Left Ear Advantage (LEA) was found for both reaction time and accuracy across children and no significant interactions with group were found.

The Word task

The present study indicates that L-type dyslexics as well as controls showed the expected REA in speed and accuracy measures when monitoring for target words, whereas P-type children did show a REA for speed but lacked ear asymmetry for accuracy. Other researchers also found that P- and L-type dyslexic children differ in ear advantage on dichotic listening tasks, with P-types tending to show a lack of ear advantage and L-types a right ear advantage (Bakker, Licht, Kok, & Bouma, 1980; Bakker & Vinke, 1985; Masutto, Bravar, & Fabbro, 1994; Morton, 1994). The REA for the control group children confirms the findings reported in a number of other studies (Zurif & Carson, 1970; Witelson & Rabinovitch, 1972; Saxby & Bryden, 1984). In corroboration with the earlier studies which have been focused solely on accuracy measures employing serial recall Dichotic Listening Test (DLT) paradigms, the present study provides evidence from accuracy measures that ear differences for P- and L-type dyslexic children in favor of the Balance model (Bakker, 1981) can be obtained by using the dichotic monitoring task developed by Bryden and MacRae (1989). However, the lack of group differences in ear advantage when it concerns speed of responding contradicts expectations based on the Balance model (Bakker, 1981) in that P-types did not differ significantly from L-types and controls. The present findings suggest that a dissociation can exist between ear advantage based on speed of responding and ear advantage based on accuracy of responses. Table 2 shows that the lack of ear advantage of P-type children has to do with a poorer performance on targets presented to the right ear, whereas performance on left ear targets is highly similar to that of L-type children and controls. This finding suggests that P-type children may have a left hemispheric deficit in processing auditorily presented language stimuli. Since this deficit seems to affect accuracy of processing more than it affects speed of processing it is tempting to conclude that P-type children may have poorer quality of auditory-verbal representations stored in the left hemisphere. It is not unlikely that less specified or more fuzzy phonological representations would hamper the discrimination of words that only differ in beginning consonants such as are employed in the present study. Similar suggestions have been put forward in order to explain poor performance on speech discrimination and production tasks in children with reading and language problems (Manis et al., 1997; Elbro & Peterson, 1998).

A number of points are of interest in discussing the present findings for words. Although the relationship between the reaction time and accuracy measures has not been investigated explicitly in the present study, the first point to be made is that it may be concluded that the present study adds another dimension to the dichotic listening studies discussed in the introduction that used accuracy measures only: for the present study also makes use of reaction time measures. The second point to be made is that the earlier studies (Bakker, Licht, Kok, & Bouma, 1980; Bakker & Vinke, 1985; Masutto, Bravar, & Fabbro, 1994) made use of a free-recall task and 3 to 4 pairs of digits as the stimulus material. It was assumed that problems with attentional biases, recall strategies and short-term memory effects could have influenced the observed laterality effects (Bryden, 1978). Because of these problems the present study made use of a stimulus detection task with divided attention and 72 pairs of word-affect combinations as stimuli, so that the effects could be attributed to hemispheric specialization with greater certainty (Bryden, Munhall, & Allard; 1983). Although earlier studies and the present study differ in several methodological aspects, the final results were similar in that P-types showed no ear advantage in accuracy whereas L-types showed a right ear advantage. Thus one may conclude that procedures used in the earlier studies and the present study are reliable methods for assessing P- and L-dyslexic subtype patterns of lateralization. The consistency found between results in earlier studies and the present one further suggests that distinguishing between reading disability subtypes might be a more fruitful approach than comparing unspecified groups of dyslexic children (e.g. Witelson & Rabinovitch, 1972; Yeni-Komshian, Isenberg, & Goldstein, 1975): these may be heterogeneous with respect to underlying etiology and pattern of lateralization. Finally, the third point to be made is that frequency counts support the ANOVA findings showing that more than 84% of the L-dyslexics and 70% of the controls showed a REA for word targets on both reaction time and accuracy, whereas 70% of P-dyslexics showed a REA in reaction time, but only 43% had a REA for accuracy. These findings indicate that the present group of P-dyslexics is more heterogeneous than the other groups with respect to ear advantage. Bakker (1981) associated P-type dyslexia with a lack of ear asymmetry or even a LEA in verbal tasks indicating an abnormal pattern of lateralization for auditory-verbal perception. But one could also explain previous group-wise findings by assuming more heterogeneity in ear advantage in the sample of P-dyslexics leading to reduced and non-significant ear asymmetry relative to L-dyslexics and controls.

The Emotion task

In the present study an overall left ear advantage was obtained for emotions similar to that reported by Saxby and Bryden (1984). Alhough our hypothesis that there would be no interactions between groups and ear advantage was confirmed, the frequency counts did not reveal a robust pattern of left ear advantage in the different groups of children. Around 57% of L-dyslexics, 67% of the P-dyslexics and 60% of the control children showed the expected left ear advantage for reaction time and accuracy, indicating that there is a considerable number of children who showed no ear advantage or a right ear advantage in the emotion task. Why our findings are not completely compatible with the fact that right hemisphere mechanisms for the recognition of affect have also been found active in children (Saxby & Bryden, 1984) is unclear. A possible explanation for the finding that left ear performances were not robust could be sought in the difficulty level of the emotion task. In the present study, the children were slower and less accurate in responding to their target emotion than to their target word. (From Table 3 one can learn that the overall accuracy in the emotion task is about 57%, whereas in the word task this is 74%.) The instruction to respond to a particular target emotion (to respond to the way certain words were pronounced) appeared difficult to grasp for some of the children even when 20 practice trials were offered, whereas the instruction to respond to a particular target word appeared to be much easier. A reduction in magnitude of ear advantage has been reported in relation to task complexity (Hiscock, 1988). Another explanation for the lack of robust left ear performances in the emotion condition is that the children were first offered the Word task and subsequently the Emotion task. It is possible that the Word task has interfered with the Emotion task, since the children heard exactly the same word-affect combinations in both tasks. Some children indeed noticed that the words were identical in both tasks, indicating that their attention had wandered to the verbal instead of the emotional dimension. This weakness in focusing on the relevant dimension is supported by findings on the Stroop interference task (Hammers, 1935) that was also administered to the dyslexic children. It appeared that P-dyslexics experienced more interference and that L-dyslexics were normal to weak performers. It is important to bear in mind that the order of administering the tasks in the present study was chosen because the Word task is easier than the Emotion task, and that less interference was expected for this order of presentation: offering the children an emotional target first could put them in a certain mood that could have interfered with the verbal task more strongly. Finally, it is possible that fatigue affected the performance in the Emotion task more than in the Word task, since it was always presented following the Word task. However, we think that the relatively smaller ear differences in the emotion task can be best explained by task difficulty and possible interference between the word and emotion dimensions.

Conclusions regarding the main findings

The present study shows that a REA is obtained when dyslexic children and controls have to monitor the verbal content of speech stimuli, whereas a LEA with the same stimulus words is observed when the children have to attend to the emotional tone in which the words are spoken. These findings are in line with those reported by Saxby and Bryden (1984) for adults. It was also found that P-type dyslexics did show a REA for speed of responding: but they showed a lack of ear advantage for accuracy in the Word task. The latter finding supports the hypotheses based on Bakker's Balance model and corroborates findings by Bakker, Licht, Kok, and Bouma (1980), Bakker and Vinke (1985), Masutto, Bravar and Fabbro (1994) and Morton (1994). The dissociation in ear advantage for P-type children may be due to a left hemisphere deficit that affects accuracy of processing more than speed of responding. In the Emotion task an overall LEA was found; no interaction between group and ear advantage was present indicating that P-, L- and control group children do not differ in laterality pattern for processing emotional intonation. This confirms our expectation. It should be noted that a considerable number of children did not show robust left ear advantages for monitoring emotional tone. We think that task complexity may have reduced general performance as well as ear asymmetry.

Additional Findings of the Present Study

Of interest, although not directly related to the main purpose of this study, are two additional findings. The first finding of interest is that analyses of emotional category (happy, angry, sad and neutral) indicated significant Group by Ear by Emotion-task interactions for both reaction time and accuracy measures. These interactions indicated that for dyslexic children performance with the left ear was more accurate than with the right ear for sad targets, whereas control children showed faster responses with the left than with the right ear in the neutral emotion condition. The dominant processing of sad tone by the right hemisphere partly supports the valence model of emotion processing which states that positive emotions are primarily processed by the left hemisphere and negative emotions by the right hemisphere (e.g., Ley & Strauss, 1986; Borod, 1993). However, an opposite lateralization pattern should have been found for the happy condition to give more support to the model. Recently, several researchers have extended the valence model by including an arousal dimension, i.e. a classification of emotions based on the level of arousal/activity associated with that particular emotion (Heller, 1993; Heilman, 1997). For example, happy as well as angry would be classified as high arousing/active, whereas sad would be classified as low arousing/inactive. An explorative analysis of the effect of high versus low arousal/activity on accuracy of the present emotion categories revealed that low arousal (sad and neutral) conditions were associated with better overall performance than high arousal (angry and happy) conditions (62.5% vs. 52.7%, respectively). This main effect tended to be stronger for controls than for dyslexics: the latter group showed an interesting interaction in that low arousing/inactive emotions (sad and neutral) were more accurately detected when presented to the left ear, whereas high arousing/active emotions (angry and happy) did not show asymmetry. These findings suggest that both valence and arousal dimensions are of importance when assessing lateralization of emotions and that future studies should include and systematically manipulate these factors.

The finding that control children show faster processing of neutral stimuli presented to the left ear is puzzling. It could be due to better discriminability of the neutral tone from the other emotional ones or to attentional bias for right hemispheric processing elicited by the affective dimension of the task (Kinsbourne,1975). However, it is unclear why such a bias would influence neutral words more than the other emotion categories.

The second finding of interest is the main effect of type of dyslexia for reaction time measures, in that the L-type children were the fastest respondents and P-type children the slowest. A closer look at Table 2 clearly shows that L-dyslexics responded faster than P-dyslexics to the word as well as to the emotion targets presented to the right and left ear. That L-dyslexics respond much faster than P-dyslexics is in accordance with the Balance model of dyslexia (Bakker, 1981) which states that L-dyslexics are fast readers and P-dyslexics are slow readers. The present findings indicate that L-dyslexics are not only fast readers, but also respond relatively quickly to word and emotional targets during auditory monitoring: this suggests that their fast processing style is not limited to reading but concerns auditory verbal/emotional processing too. However, it must be noted that the above interpretation is tentative since it appeared that the L-dyslexics were approximately 13 months older than the P-dyslexics on average and that they were also approximately ten months (one school year) ahead of the P-dyslexics in education (see DL and DAE scores in Table 1). The L-dyslexics also had a higher mastery level and shorter reading time on the AVI than the P-dyslexics (see Table 1). In addition, there was a significant negative correlation between age and reaction time with the right ear in the Word task ($r = -0.35$, $p = .011$) as well as in the Emotion task ($r = -0.32$, $p = .018$) showing that only for right ear performance there is a relationship between age and reaction time. These findings indicate that differences in response speed between the L- and the P-dyslexics could be partly due to age differences between the two groups.

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