Visual Perception and Memory Impairments in Children at Risk of Nonverbal Learning Disabilities

Irene C. Mammarella\textsuperscript{a}; Francesca Pazzaglia\textsuperscript{b}
\textsuperscript{a} Department of Developmental and Social Psychology, University of Padua, Padova, Italy
\textsuperscript{b} Department of General Psychology, University of Padova, Padova, Italy

First published on: 23 June 2010

To cite this Article

To link to this Article: DOI: 10.1080/09297049.2010.485125
URL: http://dx.doi.org/10.1080/09297049.2010.485125
Visual Perception and Memory Impairments in Children at Risk of Nonverbal Learning Disabilities

Irene C. Mammarella,1 and Francesca Pazzaglia2

1University of Padua, Department of Developmental and Social Psychology, Padova, Italy, and 2University of Padua, Department of General Psychology, Padova, Italy

Visuospatial working memory (VSWM) and visual perception were examined in two groups aged 11–13, one with children displaying symptoms of nonverbal learning disability (NLD) (n = 18) and the other a control group without learning disabilities (n = 18). The two groups were matched for general verbal abilities, age, gender, and socioeconomic level. The children were presented with VSWM tests involving visual and spatial-simultaneous processes, and also with a classical visual illusion, a classical ambiguous figure, as well as visual perception tests specifically devised for the present study. Results revealed that performance of children at risk of NLD was worse than controls in some VSWM and in visual perception tests without memory involvement; these latter required comparisons of visual stimuli and locations in space with distractors. Moreover, the two groups differed in perceiving the classical ambiguous figure. Findings are discussed in the light of both theoretical and clinical implications.

Keywords: Nonverbal learning disability; Visual perception; Working memory; Visuospatial working memory; Learning disabilities.

Introduction

A subgroup of children with learning disabilities presents a neuropsychological profile characterized by nonverbal abilities poorer than their verbal abilities. This disorder has been variously named as nonverbal learning disability syndrome (NLD; Rourke, 1995), developmental right-hemisphere syndrome (Gross-Tsur, Shalev, Manor, & Amil, 1995; Nichelli & Venneri, 1995), and visuospatial learning disability (Mammarella & Cornoldi, 2005a, 2005b). One of the most obvious identifying features of NLD is a Verbal IQ score significantly higher than Performance IQ score on formal measures of intelligence (Cornoldi, Venneri, Marconato, Molin, & Montinari, 2003; Johnson, 1987; Rourke, 1995; Weintraub & Mesulam, 1983). This finding is a direct result of the expected discrepancy between verbal, language-based cognitive abilities and nonverbal, visuospatial cognitive abilities in these children. Of course, Verbal-Performance IQ score discrepancies alone are never diagnostic in the absence of other supporting evidence. Moreover, it is worth noting that the identification procedure for children with NLD is inconsistent and...
still under debate. In fact, Solodow et al. (2006) showed that learning disability centers employ a variety of different criteria for diagnosing children with NLD.

According to Rourke (1989, 1995), the NLD syndrome is characterized by deficits grouped into three main areas: neuropsychological, academic, and social-emotional/adaptational. Neuropsychological deficits include difficulties with tactile and visual perception, psychomotor coordination, tactile and visual attention, visuospatial memory, reasoning, verbosity, and lack of prosody. Academic deficits involve difficulties with math calculations, mathematical reasoning, reading comprehension, specific aspects of written language, and handwriting. Finally, social deficits include problems with social perception and social interaction. Children with this disorder are also viewed as having substantially increased risk for internalized forms of psychopathology, primarily anxiety, and depression. Rourke’s model (1995) speculates that primary neuropsychological deficits lead to secondary deficits, which then lead to tertiary deficits, and so on. Primary neuropsychological deficits include tactile, visual perception, and motor coordination. In turn, secondary deficits (i.e., tactile and visual attention) lead to tertiary deficits, particularly in visuospatial memory, abstract reasoning, and specific aspects of speech and language. Specific, measurable impairments in academic performance, social functioning, and emotional well-being are direct by-products of this constellation of primary, secondary, and tertiary neuropsychological deficits.

Visuospatial working memory (VSWM) has been specifically explored in children with NLD. Cornoldi, Dalla Vecchia, and Tressoldi (1995) compared children with high- and low-visuospatial intelligence but matched for other characteristics, finding specific deficits of VSWM in the former. Cornoldi, Rigoni, Tressoldi, and Vio (1999) investigated the generation and manipulation of mental images in working memory and found that NLD children failed in tasks requiring the generation of mental images. Other studies examined differences in verbal and visuospatial memory. Liddell and Rasmussen (2005), for example, compared performance of children with NLD on the visual and verbal memory subtests of the Children’s Memory Scale (CMS; Cohen, 1997). Scores on measures of visual memory for children with NLD were significantly lower than for their verbal memory scores. Moreover, Mammarella and Cornoldi (2005b) showed that children with NLD performed the Corsi blocks task more poorly than typical development, proving particularly poor in the backward version compared to controls or their own performance in the forward version.

A few studies considering visual perception performances in children with NLD have also been carried out. Rourke (1995) suggests that children with NLD show impaired discrimination and recognition of visual detail and visual relationships. As stated by Rourke, simple visual discrimination, especially for material that can be verbalized, usually approaches normal levels with advancing years. Instead, complex visual-spatial-organizational skills tend to worsen relative to age-based norms. However, experimental data have never been reported. Rourke’s studies (Casey, Rourke, & Picard, 1991; Pelletier, Ahmad, & Rourke, 2001; Rourke, & Strang, 1978) considered the measures of sensory perception exams, Grip Strength, and the Tactual Performance test (Reitan & Davison, 1974), but none of these measured visual perception per se. Only one single case study has examined this: Roman (1998) reported that CK, a 15-year-old boy attending 9th grade, performed lower than 1st percentile in the Benton Judgment of Line Orientation test (Benton, Hamsher, Varney, & Spreen, 1983) requiring the matching of two angled lines shown on a card also containing 11 numbered lines displayed below.
In contrast, there is evidence that children with NLD are impaired in visuoconstructive abilities. In a study by Gross-Tsur et al. (1995) of 20 children with NLD, the authors reported that 15 of them showed poor performance on the Bender Gestalt test (Bender, 1938); poor performances were also shown by 9 children presented with the Rey-Osterrieth complex figure test (Osterrieth, 1944; Rey, 1941). The single case described by Roman (1998) performed below 1st percentile in the test of visual-motor integration (VMI; Beery, 1982). Also Mammarella et al. (2006), reporting three single cases, revealed that all children obtained low scores in both the Rey-Osterrieth complex figure test and the VMI. However, failures in visuoconstructive abilities do not correspond to failures in visual perception tests; moreover, if, in some cases, they might be correlated, experimental data supporting a relationship between visuoconstructive ability and visual perception are not reported.

The main aim of the present research was to investigate VSWM and visual perception difficulties in children at risk of NLD compared to controls matched for verbal general abilities, age, gender, and sociocultural level. We used a number of visual perception and memory tests, where the same stimuli were presented in either a perception or memory condition during a single experimental session. Moreover, in order to investigate perceptual deficits in depth, a classical visual illusion and a classical ambiguous figure were presented. Our aim was to examine whether children in the NLD group, compared to controls, were impaired in both the visual perception and the memory tests; confirmation would reinforce the idea that perceptual and VSWM deficits tend to coexist in children with NLD. It should be noted that the children in our NLD group were not diagnosed as having NLD, but as displaying some of the symptoms as identified by their teachers through the Short Visuospatial (SVS) Questionnaire (Cornoldi, Venneri, Marconato, Molin, & Montinari, 2003), and through subtests (one spatial, one verbal) of the Primary Mental Ability (PMA; Thurstone & Thurstone, 1963).

To examine VSWM aspects, passive simple-span tasks (Cornoldi & Vecchi, 2003) involving recognition were used, selected from a VSWM battery (Mammarella, Toso, Pazzaglia, & Cornoldi, 2008). Specifically, children were presented with two visual tests (requiring recognition of shapes and textures), and two spatial-simultaneous tests (requiring recognition of spatial locations presented simultaneously) (see also Mammarella, Pazzaglia, & Cornoldi, 2008).

In order to investigate visual perception processes in children with NLD, we devised a series of tests deriving our stimuli from the VSWM tests. In the visual perception tests a target figure had to be compared with four distractors, and the one identical to the target identified. Consequently, neither storage nor recall of information was required. The children were also presented with two classical visual perceptual pictures: the Rubin vase-face picture (Rubin, 2000) and the Kanizsa triangle illusion (Kanizsa, 1955).

METHOD

Screening Phase

Participants and selection criteria. The initial sample involved 478 children (236 males, 242 females) aged 11 to 13 years ($M = 149.97$ months; $SD = 10.96$), with 166 from 6th grade, 148 from 7th grade, and 164 from 8th grade. Identification of the children at risk of NLD and the control group (CG) was carried out on the basis of difficulties detected by their teachers through the SVS Questionnaire (Cornoldi et al., 2003). General
verbal and visuospatial abilities were evaluated using the Verbal Meaning and Spatial Relations subtests of the Primary Mental Ability Test (PMA; Thurstone & Thurstone, 1963), respectively. For all children parental consent was obtained prior to testing.

The SVS Questionnaire is a tool developed for preliminary identification of children with NLD. Teachers were asked to evaluate whether a child presented a given characteristic on a 4-point scale. The SVS Questionnaire offers a visuospatial score (range 10–40) based on 10 items with demonstrated sensitivity in detecting some of the deficits that represent critical features for NLD (Cornoldi et al., 2003). The questionnaire includes a further two items used to obtain an indicative verbal learning score (range 2–8), and one allowing a teacher’s estimate of the child’s sociocultural level (range 1–4; 1 = high sociocultural level, 2 = medium-high; 3 = medium-low; 4 = very low). Children referred to as having a very low sociocultural level were not included in the groups, in order to avoid false positives.

The inclusion criteria of the children at risk of NLD were the following: (a) visuospatial scores of the SVS Questionnaire lower than the 20th percentile; (b) scores lower than two SDs in the Spatial Relations subtest of the PMA; (c) verbal scores of the SVS Questionnaire higher than the 50th percentile; (d) scores close to the mean of our whole sample in the Verbal Meaning subtest of the PMA. Using these criteria we were able to identify children with good verbal skills and poor visuospatial abilities.

In contrast, the inclusion criteria of the CG group were the following: (a) scores equal to or higher than the 50th percentile in both visuospatial and verbal scores of the SVS Questionnaire; (b) performance close to the mean in both PMA subtests (Spatial Relations and Verbal Meaning).

**Experimental Phase**

**Participants.** From the whole sample, only 18 children (6 males, 12 females) obtained a visuospatial score below the 20th percentile and a verbal score above the 50th on the SVS questionnaire; performance in the PMA Spatial Relations subtest lower than two SDs of the mean; and Verbal Meaning performance close to the mean for the whole sample. These children were recruited for the study as belonging to the group at risk of NLD. The CG children (8 males, 10 females) were selected in order to differ on only the visuospatial score of the SVS and the PMA Spatial Relations subtest and were matched for age, gender, verbal score of the SVS Questionnaire, F(1, 34) = 25.23, MSE = 17.20, p < .001, η² = .43, and the PMA Spatial Relations subtest, F(1, 34) = 81.53, MSE = 17.09, p < .001, η² = .89, but similar in the verbal score of the SVS Questionnaire F(1, 34) = 3.07, MSE = 1.29, p < .09, the PMA Verbal Meaning subtest, F(1, 34) < 1, age F(1, 34) < 1, socioeconomic level U Mann-Whitney = 145.0, p = .61, and gender χ²(1, N = 36) = 0.47 p = .49.

**Materials and procedure.** Tests were administered in a quiet room at the child’s school during a single, individual session. In order to avoid biasing of performance in any test through effects of practice or fatigue, test presentation order was counterbalanced according to a randomized Latin square.

In particular, children were presented with a total of 10 tasks: four VSWM tests, four visual perception tests (with stimuli derived from the VSWM tests), and two classical
perception figures, the Rubin vase-face picture (Rubin, 2000) and the Kanizsa triangle illusion (Kanizsa, 1955).

**Visuospatial working memory tests.** Participants were presented with four computerized tests from a VSWM test battery (Mammarella, Toso, et al., 2008). Two involved visual passive processes, requiring recognition of either a shape or texture, and the other two involved spatial-simultaneous processes, requiring recognition of presented locations. The four tests all had the same structure (see Figure 1). The children were asked to decide if a series of figures/locations were the same as or different from the one previously presented: In the tests, following a first stimulus presentation, either the same stimulus or one with a change of just one element was presented. These were followed by a response screen containing two letters U (uguale = same) and D (diverso = different): The child had to respond by pressing one of two keys on the keyboard. Before starting the experiment, the children spent a few minutes practicing to familiarize themselves with the two keys and to ensure their function was clear; before administration of each task, participants were given two practice trials with feedback.

For each test, half the items required a “same” response and half a “different” response. The tests progressed from the second (two stimuli) to the eighth (eight stimuli) level, with three items at each level. For scoring, proportions of correct responses were calculated.

**Visual tests**

The nonsense shapes task. Children were presented with a series of two to eight nonsense figures and had to decide whether or not these figures were identical to the previous ones. At the second level two figures were presented, at the third level three figures, and so on. At the beginning of the procedure a blank screen appeared for 1000 ms, followed by another blank screen for 500 ms, and then the nonsense figures (3000 ms), followed by another blank screen for 500 ms. After presentation of a fixation point for 1500 ms, either the same series of figures or a series differing in one figure was presented for the recognition task, followed by a response screen with the letter U (uguale = same) or D (diverso = different): The child had to respond by pressing one of two keys on the keyboard.

The toy balloons recognition task. Participants had to recognize if textures inside the balloons were the same or different. Presentation times and other procedural aspects were the same as those for the previous visual task.

**Spatial-simultaneous tests**

The simultaneous-lines task. The stimuli were derived from Miyake, Friedman, Rettinger, Shah, and Hegarty (2001). Participants were presented with 5×5 matrices composed of 25 small black dots. Black lines joining up the dots appeared simultaneously, and participants had to decide whether or not there was a line in a different location compared with a previously presented stimulus. After a grey screen of 1000 ms, a display of 25 small black dots appeared for 500 ms on the screen and then a variable number (depending on complexity level, from 2 to 8). Black lines joining up the dots were presented for 2500 ms, followed by another delay of 500 ms. After a fixation point of 1000 ms the presentation was repeated but with a line joining two dots possibly in a different location.
Figure 1 The tests used in the present study: visual working memory tests (e.g., the nonsense shapes task and the toy balloons recognition task); spatial-simultaneous tests (e.g., the simultaneous lines task and the simultaneous dot matrix); and visual perception tests (e.g., the perceptual nonsense shapes task, the perceptual toy-balloons task, the perceptual simultaneous-lines task, the perceptual dot matrix task, the Rubin vase-face picture, and the Kanizsa triangle illusion).
The simultaneous dot matrix. The task involved $5 \times 5$ matrices in which red dots appeared simultaneously. Presentation times were identical to those of the simultaneous-lines task, and participants had to decide if all the dots appeared in the same or in different locations.

**Visual perception tests.** The stimuli of the four visual perception tests were derived from the VSWM tests; two tasks required recognition of either shapes or textures, the other two requiring recognition of presented locations. The four tests had the same structure. The children were asked to decide which figure of a set of four distractors was identical to the target figure (see Figure 1). Target and distractors were presented simultaneously on the screen and remained visible until the child pressed a key as response; each distractor was associated with a response key (i.e., 1, 2, 3, 4). Before starting the experiment, the children spent a few minutes practicing to familiarize themselves with the keys and to ensure their function was clear; before administration of each task, participants were given two practice trials with feedback.

For scoring, proportions of correct responses and reaction times (considering only correct responses) were calculated.

**Perceptual nonsense shapes task.** The children were presented with a target nonsense figure shown on the upper side of the screen plus four distractors and had to decide which of these figures was identical to the target. Each distractor was associated with a number (1, 2, 3, 4 from left to right on the screen). Target and distractors appeared simultaneously on the screen, so excluding involvement of visuospatial memory. A total of 20 target figures were presented. At the beginning of the procedure a blank screen appeared for 1000 ms, followed by the nonsense figures (self-paced); the children had to press the correct response key (1, 2, 3, or 4) to select the figure identical to the target. A blank screen of 1000 ms was then presented, then after presentation of a delay grey screen of 1000 ms another series of figures was presented.

**Perceptual toy balloons task.** Children were presented with a target toy balloon presented in the upper part of the screen plus four distractors below and had to decide which of these balloon figures had an interior texture identical to the target. Presentation times and other procedural aspects were the same as for the previous task.

**Perceptual simultaneous-lines task.** The stimuli were derived from Miyake et al. (2001). Participants were presented with $5 \times 5$ matrices composed of 25 small black dots. Both target and distractors contained six black lines joining up the dots; participants had to identify the distractor identical to the target figure. Presentation times and other procedural aspects were the same as for the previous tasks.

**Perceptual dot matrix task.** Both target and distractors contained five red dots inside a $5 \times 5$ matrix; participants had to identify the distractor identical to the target. Presentation times were the same as for the previous tasks.

**Rubin vase-face picture and Kanizsa triangle illusion.** The children were presented with two classical figures printed on separate A4 sheets for 120 s each. For the Rubin vase-face picture, participants were informed of the ambiguity then had to say what they could see, while for the Kanizsa triangle illusion they just had to say what they could see.
For the Rubin picture a score of 1 was given if only one of the two figures was seen, and a score of 2 if both the vase and face were seen. For the Kanizsa illusion a score of 1 was given if the child did not see the white triangle and a score of two if they did see it (see Figure 1).

RESULTS

Statistical Analysis

One-way ANOVAs were performed to compare the groups on both the VSWM and the visual perception tests, while chi-squares were performed to compare the number of children able to see the reversible picture and the optical illusion. Significant \( \alpha \) was set at \( p < .05 \). Descriptive statistics are given in Table 1.

Visuospatial Working-Memory Tests

CG children outperformed those at risk of NLD in the nonsense shapes task, \( F(1, 34) = 4.59, \text{MSE} = .61, p = .039, \eta^2 = .12 \); simultaneous-lines task, \( F(1, 34) = 11.84, \text{MSE} = .04, p = .002, \eta^2 = .26 \); and simultaneous dot matrix task, \( F(1, 34) = 7.59, \text{MSE} = .03, p = .009, \eta^2 = .18 \). However, the two groups did not differ in performance on the toy balloons recognition task, \( F(1, 34) = 1.58, \text{MSE} = .04, p = .22, \eta^2 = .04 \).

Visual Perception Tests

Regarding mean proportion of correct responses, groups were significantly different in the perceptual nonsense shapes task, \( F(1, 34) = 8.09, \text{MSE} = .005, p = .007, \eta^2 = .19 \); perceptual toy balloons task, \( F(1, 34) = 5.37, \text{MSE} = .004, p = .027, \eta^2 = .14 \); perceptual simultaneous-lines task, \( F(1, 34) = 8.81, \text{MSE} = .026, p = .005, \eta^2 = .21 \); and perceptual dot matrix task, \( F(1, 34) = 5.89, \text{MSE} = .036, p = .021, \eta^2 = .15 \). No differences were observed in reaction times between groups, in particular for the perceptual nonsense

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Descriptive Statistics of VSWM and perceptual Tests, Mean Proportion of Correct Responses and Reaction Times (Standard Deviations in Parentheses) for NLD and controls (CG).</th>
</tr>
</thead>
<tbody>
<tr>
<td>NLD</td>
<td></td>
</tr>
<tr>
<td>M (SD)</td>
<td></td>
</tr>
<tr>
<td>VSWM Tests</td>
<td></td>
</tr>
<tr>
<td>Nonsense shapes</td>
<td>.39 (.26)</td>
</tr>
<tr>
<td>Toy balloons</td>
<td>.42 (.21)</td>
</tr>
<tr>
<td>Simultaneous lines</td>
<td>.54 (.16)</td>
</tr>
<tr>
<td>Simultaneous dot matrix</td>
<td>.58 (.24)</td>
</tr>
<tr>
<td>Visual Perception Tests – Accuracy</td>
<td></td>
</tr>
<tr>
<td>Perceptual nonsense shapes</td>
<td>.89 (.09)</td>
</tr>
<tr>
<td>Perceptual toy balloons</td>
<td>.92 (.08)</td>
</tr>
<tr>
<td>Perceptual simultaneous lines</td>
<td>.47 (.21)</td>
</tr>
<tr>
<td>Perceptual dot matrix</td>
<td>.62 (.19)</td>
</tr>
<tr>
<td>Visual Perception Tests – Reaction Times (ms)</td>
<td></td>
</tr>
<tr>
<td>Perceptual nonsense shapes</td>
<td>2695.22 (726.51)</td>
</tr>
<tr>
<td>Perceptual toy balloons</td>
<td>2211.35 (471.43)</td>
</tr>
<tr>
<td>Perceptual simultaneous lines</td>
<td>4481.42 (1393.28)</td>
</tr>
<tr>
<td>Perceptual dot matrix</td>
<td>5518.93 (2292.21)</td>
</tr>
</tbody>
</table>
shapes, \(F(1, 34) = 1.52, \text{MSE} = 333282.5, p = .23, \eta^2 = .04\); perceptual toy balloons, \(F(1, 34) = 3.15, \text{MSE} = 185510.2, p = .09, \eta^2 = .08\); perceptual simultaneous-lines, \(F(1, 34) < 1\); and perceptual dot matrix, \(F(1, 34) = 2.17, \text{MSE} = 4746916, p = .15, \eta^2 = .06\).

For the Rubin vase-face picture, 83.3\% of children at risk of NLD could see only one figure (i.e., either the vase or face), the remainder seeing both. Instead, 61.1\% of the CG children could see both figures, the remainder seeing only one; \(\chi^2(1, N = 36) = 7.48, p = .006\). The difference between groups was not found in the Kanizsa triangle illusion: the triangle could be seen by 38.9\% of children at risk of NLD and 50\% of the CG, \(\chi^2(1, N = 36) = 0.45, p = .50\).

**DISCUSSION**

To date there has been no report of visual perception processing in children with NLD. Although Rourke (1989, 1995) indicates visual perception as a neuropsychological deficit of children with NLD, to the best of our knowledge there have been no studies analyzing visual perception deficits in this clinical population. In contrast, a growing number of studies have examined memory impairments in children with NLD, comparing verbal versus visuospatial memory (Liddell & Rasmussen, 2005) and also studying VSWM in depth (Cornoldi et al., 1995; 1999; Mammarella & Cornoldi, 2005a; Mammarella et al., 2006).

The main goal of the present research was to investigate VSWM and visual perception deficits in children at risk of NLD. Results revealed that children at risk of NLD failed in three out of four VSWM tasks, namely one visual and two spatial-simultaneous. This result is consistent with previous findings suggesting that children with NLD are usually impaired in VSWM tasks (Cornoldi et al., 1995, 1999, 2003; Mammarella et al., 2006). However, the novelty of the present research is the finding of failures of children at risk of NLD in visual perception tasks. Children at risk of NLD were shown to score more poorly than controls in all the visual perception tasks specifically devised for this current study; though differences were observed in accuracy rather than reaction times. It should be noted that the instructions stressed the need to perform the task as quickly and accurately as possible. Most importantly, a trade-off between speed and accuracy was not observed.

In our view, our results are relevant to the clear distinction of the critical failures of children with NLD. To our knowledge, before this present study no systematic analysis of visual perceptual deficits in children with NLD had ever been reported. Rourke (1995) hypothesized a visual perceptual deficit in children with NLD but did not carry out experiments to examine this proposition in depth. However, we cannot completely rule out our visual perceptual tasks involving VSWM processes to some extent. The neuropsychological literature on adult patients shows that some visuo-perceptual disorders (e.g., constructional apraxia and spatial neglect) can be explained by spatial working-memory deficits due to a failure to remap spatial locations through eye movements (Pisella & Mattingley, 2004); this possibility could be explored in further research. However, our results — obtained through testing a developmental sample, in particular children at risk of NLD — can be used to seek a consensus for the diagnosis of children with NLD and to identify the tasks that are most useful in distinguishing children with NLD from typical development.

Our results also showed that in the Rubin vase-face picture, controls outperformed children at risk of NLD. The Rubin picture and Kanizsa illusion examined two different aspects of visual perception — ability to reverse ambiguous figures and ability to perceive an optical illusion, also known as a subjective or illusory contour. For the case of ambiguous figures, some adults do perceive reversals without being informed of the ambiguity. This might be
because they have prior experience with such figures. Since young children are unlikely to have had such an experience, Rock, Gopnik, and Hall (1994; see also Gopnik & Rosati, 2001) examined spontaneous reversal in preschoolers. When uninformed of the ambiguity and told to look at a figure, no child ever reported reversal. These findings support the idea that in order to achieve reversal of an ambiguous figure the viewer must be aware of the ambiguity. Moreover, even after the ambiguity had been clearly pointed out, informed younger children were particularly unlikely to reverse. This suggests that either the necessary conceptual framework or the ability to bring about reversal develops during the preschool years (Doherty & Wimmer, 2005). In our study, after being informed, only 16.7% of children at risk of NLD could see both the vase and face in the Rubin picture, while 61.1% of controls could see both. For the optical illusions, our results showed that only 50% of controls perceived the Kanizsa triangle, the other 50% reporting three small triangles and three partial circles. Moreover, there were no differences between children at risk of NLD and controls.

The fact that children at risk of NLD had difficulty in performing visual perceptual tasks and an inability to reverse ambiguous figures could be related to their difficulty in analyzing and synthesizing novel and other complex situations (Rourke, 1995) but also to an involvement of the central executive component of working memory. Rourke (1995) suggested that difficulties in perceiving stimuli might explain memory impairments but to date no empirical evidence has emerged to demonstrate that visual perceptual deficits cause visuospatial memory deficits. Moreover, studies on children with early brain injury showed that their nonverbal intelligence is impaired relative to verbal intelligence in many early-onset neurological disorders, as found for children with NLD: cystic periventricular leukomalacia (Fedrizzeti et al., 1993; Jacobson, Ek, Fernell, Flodmark, & Broberger, 1996; Woods, Weinborn, Ball, Tiller-Nevin, & Pickett, 2000), spastic hemiplegia (Ballantyne, Scarvie, & Trauner, 1994), and hydrocephalus (Brookshire et al., 1995). Visual perception impairment has also been reported for congenital, perinatal, or neonatal neurological abnormalities (Ito et al., 1996, 1997; Koeda & Takeshita, 1992). However, Stiers, De Cock, and Vandenbussche (1999; Stiers et al., 2001) demonstrated that there is no causal relationship between visual perception and nonverbal intelligence impairments, but that deficits in visual perception and in nonverbal intelligence tend to coexist as two separate and irreducible disorders in children with early brain injury. Our results therefore leave open the question of whether the difficulties in visuospatial memory and academic achievement typically encountered by children with NLD are due to the more basic deficit of visual perception; however, in agreement with the studies cited above, we believe that all deficits in perception, VSWM, and academic achievement represent critical features of children with NLD, without causal relationship among them.

Conversely, further evidence is required and a number of critical issues need addressing. As noted above, the children at risk for NLD of this study were not diagnosed as having a nonverbal learning disability but instead showed some of the symptoms, specifically in handling visuospatial materials, typically associated with Forrest’s (2004) visual-spatial disability category of nonverbal learning disability. This mirrors the first of two impairment categories of NLD children proposed by Forrest: Those with visuospatial deficits fall into a visual-spatial disability category\(^1\), with a separate diagnostic category

\(^1\)In his study, Forrest (2004) used the visuospatial processing subtests of the NEPSY test battery (Korkman, Kirk, & Kemp, 1997) in order to assess visuospatial abilities of children with NLD. The author found that children with NLD differed from controls and from verbal learning disabled children only on the block construction subtest.
(social processing disorders) for those whose social skills deficits are primary and impair everyday functions. Further research might replicate this study on children with an actual diagnosis of NLD; although the finding of visual perception deficits in children at risk of NLD could suggest that the same deficit will be detected in a diagnosed population of NLD.

The presence of visual perception deficits in children at risk of NLD also has clinical implications, in terms of not only the type of treatment but also the clinical diagnosis of children with NLD: Better knowledge of clear and well-documented symptoms should prove particularly useful since NLD is not currently included in either the International Classification of Diseases (ICD-10; WHO, 1992) or the Diagnostic and Statistical Manual of Mental Disorders, text revision (DSM-IV-TR; American Psychiatric Association, 2000). Our results suggest that the investigation of both VSWM but also, crucially, of visual perception should be important in the diagnosis of children with NLD, and that our test battery can be a useful instrument for both researchers and clinicians. In summary, the novel finding of this research is that children at risk of NLD failed not only in VSWM tasks but also in visual perception tasks requiring comparison of visual stimuli and locations in space without any memory involvement and an inability to reverse an ambiguous figure.

REFERENCES


