Deficits in the Processing Of Local and Global Motion in Very Low Birthweight Children

By

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THE UNIVERSITY OF MANITOBA

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Abstract

Prematurity is associated with a number of impairments in visual function. This study evaluated the impact of premature birth on the development of visual motion processing in a group of very-low-birthweight (<1500 gm), 5-8 year old children (n = 19). Premature children's sensitivity to local and global motion was compared to that of control children (n = 19) born at term. Sensitivity to local motion was assessed by measuring thresholds for detecting luminance-defined (first-order) or contrast-defined (second-order) stimuli. Sensitivity to global motion was assessed by measuring coherence thresholds for random dot kinematograms. For local motion, prematurity was associated with reduced sensitivity to first-order and second-order stimuli. The mean threshold for correct discrimination of direction of first-order motion was 2% higher among premature children than controls; for second-order motion, premature children's mean thresholds were 48% higher than controls'. Difficulties in perceiving both types of local motion stimuli were not related to impaired stereoacuity. Sensitivity to global motion was also impaired in premature children, with coherence thresholds being three times higher than in the control sample. A triple dissociation between sensitivity to first- and second-order local cues and global cues was observed, suggesting that these three types of motion processing involve different neural mechanisms. Together, these findings suggest that premature children show deficits on all aspects of motion vision tested, with the level of impairment increasing with increasing computational complexity. These findings serve to increase our understanding of the impact of premature birth on the development of motion-processing subsystems in humans.

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Deficits in the Processing of Local and Global Motion in Very Low Birthweight Children

Over the past decade advances in obstetric and neonatal care have increased markedly the survival rate of premature children. The development of technology that pushes back the limits of extrauterine life necessitates research into the possible long-term, deleterious effects of premature birth on surviving infants. The results of several prospective studies suggest that premature children born at very-low-birthweight (VLBW;<1500 gm) are more likely than children born at term to be delayed in scholastic achievement and to show deficits in attention, language skills, social competence, and athletic ability (Hille et al., 1994; Klebanov, Brooks-Gunn, & McCormick, 1994), despite often scoring in the normal range on tests of intelligence (Saigal, Rosenbaum, Szatmari, & Campbell, 1991). In addition, problems with visual development are noted frequently. In this regard, retinopathy of prematurity (ROP), a disorder characterized by abnormal proliferation of retinal blood vessels, poses the most evident threat to preterm babies and can, in severe cases, lead to blindness. Other ocular complications associated with VLBW status include decreased visual acuity, strabismus (crossed-eyes), nystagmus (rapid, jerky eye movements), amblyopia (lazy eye), and myopia (near-sightedness) (Burgess & Johnson, 1991). Visuomotor and visuospatial deficits are frequently associated with periventricular brain damage (PVBD), the most common form of brain injury seen in premature infants (Jakobson, Frisk, Knight, Downie, & Whyte, 2001; Jongmans, et al., 1996; Olsén et al., 1998).

The increased prevalence of visual problems in VLBW children raises concerns about long-term neurodevelopmental, psychoeducational, and functional outcomes. Much of the research in this area, however, is characterized by complex research designs and

confounded variables that make interpretations difficult. For example, some researchers include in their VLBW samples children who were born small-for-gestational age (i.e., birthweight more than two standard deviations below the mean for their gestational age), in addition to those who were appropriately grown for their gestational age – despite recent findings suggesting that the degree of growth restriction is negatively associated with various indices of performance (e.g., Hutton, Pharoah, Cooke & Stevenson, 1997; Martikainen, 1992). Other work involving children born at low birthweight (<2500 gm) has revealed a relationship between sociodemographic variables (e.g., maternal education level, annual household income) and outcome (Hack & Breslau, 1986; Vohr, Coll & Oh, 1988). Failure to control for the possible impact of these factors can make it difficult to determine the impact of other variables on developmental outcomes in this high-risk population.

The present study examined visual development in a group of appropriately grown, very-low-birthweight children of normal intelligence, and a full-term control sample matched to the preterm sample in terms of age-at-testing, parental education, and family income. The experimental tests tapped into one specific domain of visual function, namely visual motion processing. This type of visual analysis is regarded as one of the most fundamental aspects of normal vision.

Visual Motion Processing in the Primate Brain

The major visual pathway in humans is the geniculostriate pathway, which connects the retina to primary visual cortex (V1) via the lateral geniculate nucleus of the thalamus. This pathway has two distinct subdivisions (Cornelissen & Hansen, 1998). The magnocellular pathway originates in a particular class of retinal ganglion cells that have

their first synapse in the magnocellular layers of the lateral geniculate nucleus. The parvocellular pathway originates in a distinct class of retinal ganglion cells, terminating in the parvocellular layers of the lateral geniculate nucleus. This anatomical segregation of the pathways is maintained in the optic radiations, and at the level of primary visual cortex (V1).

Numerous studies have helped to elucidate the functional segregation of these two pathways. The temporal resolution of cells in the M pathway makes them particularly sensitive to visual motion, while cells in the P pathway have superior spatial resolution and colour sensitivity, making them well-suited to extract information about visual form (Livingstone & Hubel, 1988; Tassinarai, Marzi, DiLollo, & Campara, 1999). These observations fit nicely with findings from studies exploring the effects of selective lesioning of these pathways in macaque monkeys, whose brains are thought to be sufficiently akin to the human brain to warrant application of anatomical data to human vision (Cornelissen et al., 1998). When parvocellular damage is produced through the administration of ibotenic acid, noticeable deficits in color perception occur. In contrast, deficits in motion perception follow selective magnocellular lesions (Merigan & Maunsell, 1993). Although the functions of these two pathways are not completely independent, they are pronounced enough to indicate a high degree of segregation.

Like the geniculostriate pathway, the cortical visual system of primates is also organized, both anatomically and functionally, into two broad pathways or streams (Milner & Goodale, 1995). The occipitotemporal or ventral stream processes stimulus properties such as color and form and is critically involved in object recognition (Martin-Loeches, Hinojosa, & Rubia, 1999). It receives major inputs from both the magnocellular

and the parvocellular subcortical pathways (Hermann, 2002). Inputs to the occipitoparietal or dorsal stream, in contrast, originate primarily from the M pathway and project on to the extrastriate middle temporal area (area MT) and adjacent motion sensitive areas before reaching the posterior parietal lobe (Cornelissen & Hansen, 1998). The dorsal stream's role in the perception of motion and depth makes it critical for many visuospatial functions, including the ability to localize objects in space (Ungerleider & Mishkin, 1982). In addition, the dorsal stream is intimately involved in tasks such as the visual guidance of motor responses, and egocentric orientation (Milner & Goodale, 1995).

Damage to or dysfunction in the M pathway, or in key dorsal stream areas such as MT, impairs aspects of motion processing. Monkeys who have cortical visual area MT removed show deficits on tasks of motion perception (Marcar & Cowey, 1992), whereas lesions of the human analogue of area MT cause akinetopsia, or visual motion blindness (Zihl, von Cramon, & Mai, 1983). Motion-processing impairments have also been described and linked to dorsal stream dysfunction in a number of developmental disorders, including autism (Spencer et al., 2000), Williams' syndrome (Atkinson et al., 1997), and developmental dyslexia (e.g., Cornelissen & Hansen, 1998; Felmingham & Jakobson, 1995; Demb, Boynton & Heeger, 1998).

Local and global motion processing subsystems. Motion detection and analysis involves several distinct processes. The first stage of low-level motion analysis -- local motion processing -- involves the perception of motion discerned from a single point. Cells responsive to this type of motion are first encountered in primary visual cortex (Adelson & Bergen, 1985; Van Santen & Sperling, 1984).

At the second stage of low-level motion processing, perceptual grouping of several local motion cues is performed; this involves global motion analysis. Lesion studies in monkeys carried out by Newsome and colleagues have produced compelling evidence that global motion processing involves area MT and the adjacent area MST (Newsome & Paré, 1988). Damage to the human homologue of MT has also been shown to elevate thresholds for global motion detection (Schenk & Zihl, 1997).

Low-level motion signals can be processed in the visual system on the basis of either first-order (Fourier) or second-order (non-Fourier) stimulus properties (Chubb & Sperling, 1988). The former refers to motion defined by spatiotemporal variations of luminance, and the latter by spatiotemporal variations in image characteristics other than luminance, such as contrast, depth, or texture. Studies indicate that, at least initially, first- and second-order motion are encoded by separate neural mechanisms. Findings from numerous psychological (Vaina, LeMay & Grzywacz,1993), psychophysical (Ledgeway & Smith, 1994; Nishida, Ledgeway, & Edwards, 1997) and electrophysiological (Zhou & Baker, 1993, 1994, 1996) studies support the idea of separate cortical mechanisms supporting first- and second-order motion processing.

Recently, Vaina, Cowey, and Kennedy (1999) used high-resolution functional magnetic resonance imaging to identify structural and functional dissociations between first- and second-order motion. The performance of two patients with focal unilateral lesions was assessed on a number of psychophysical tests. Patient RA, who had a unilateral lesion in the medial occipital lobe, showed impairment on tests of first-order motion but not on those of second-order motion. Conversely, FD, whose lesion was in the dorsolateral occipito-temporal lobe, performed normally on tasks of first-order motion but

poorly on those of second-order motion.

Further support for a dissociation lies in the differential developmental time courses for the maturation of sensitivity to first- and second-order motion. Meghji et al. (2003) investigated the development of motion perception by comparing the minimum amount of luminance (a first-order cue) and contrast (a second-order cue) necessary to judge the direction of motion in both children and adults. For each motion type, thresholds were obtained for a slow velocity (1.5 deg/s) and a faster velocity (6 deg/s). At the slower velocity, 5-year-olds' thresholds were reduced slightly but equally for both first- and second-order stimuli. However, at the faster velocity (6 deg/s), the differences between children and adults were 8 times greater for second-order motion than for first-order motion. These findings suggest that there is a differential timecourse for the development of sensitivity to the two motion types, at least at the faster velocity.

Studies of Motion-Processing in Children with Early Visual Deprivation or Stimulation

One strategy used to identify and describe the visual systems supporting motion is to compare children with normal and abnormal development on tests of motion-processing. Lewis, Ellemberg, Maurer, Defina and Brent (2000) compared 19 patients treated for congenital cataracts with an age-matched control group. Children in the clinical sample exhibited abnormal sensitivity to luminance- and contrast-defined motion cues generated with horizontal sinusoidal gratings. Similarily, it has been found that deprivation due to monocular and binocular cataracts significantly impairs a patient's ability to discriminate the direction of global motion (Ellemberg, Lewis, Maurer, Brar, & Brent, 2002). These findings illustrate the possible consequences of early ocular deprivation on the maturation of the central visual system.

Rather than studying children who had experienced postnatal ocular deprivation, Downie, Jakobson, Frisk and Ushycky (2003) investigated the global integration of perceptual cues in a group of children who had experienced unusually early visual stimulation because they were born prematurely. Thirty-five extremely-low-birthweight (<1000 gm) children, born at 24 to 30 gestation, were tested between the ages of 8 and 14 years using a motion-defined form recognition task. The kinetic shapes in this task become visible to the typical viewer when the motion of the dots comprising the background opposes that of dots comprising the figure. The computations that allow one to discern these kinetic shapes are thought to take place in visual area KO, which receives a strong input from area MT (Van Oostende, Sunaert, Van Hecke, Marchal, & Orban, 1997). In the study by Downie et al. (2003), the preterm children were divided into two groups based upon the presence or absence of periventricular brain damage (PVBD), and the performance of these two groups was compared to that of a full-term control group. Preterm children showed a marked impairment on this task, with 71% of the sample performing at a level at least three standard deviations below controls. Contrary to expectations, however, there did not seem to be an association between the level of impairment on this motion task and the presence of PVBD.

It is possible that cranial ultrasound scans were simply not sensitive enough to detect subtle damage that may have been present in the brains of the preterm children classified as being free of PVBD. It is also possible, however, that a history of even mild, spontaneously regressed, ROP puts a child at risk for altered development of motion processing systems; the two groups of preterm children in the Downie et al. (2003) study were matched for severity of ROP. It has recently been shown that mild (spontaneously

regressed) ROP is associated with rod photoreceptor dysfunction (Fulton, Hansen, Petersen & Vanderveen, 2001). Given that there is a strong rod input to the M pathway (D'Zmura & Lennie, 1986; Gouras & Link, 1966; Lee, Pokorny, Smith, Martin & Valberg, 1990; Lee, Smith, Pokorny & Kremers, 1997; Purpura, Kaplan & Shapley, 1988; Sun, Pokorny & Smith, 2001; Virsu & Lee, 1983; Virsu, Lee & Creutzfeldt, 1987; Wiesel & Hubel, 1966) it is possible that even mild ROP would be associated with deficits in motion processing.

The results of other research raise the possibility that the atypical visual exposure experienced by these infants may, in itself, interfere with the normal development of motion processing systems in the brain. Dowdeswell, Slater, Broomhall and Tripp (1995) presented the first detailed account of visual performance in premature children who had escaped cerebral and ocular pathology. Sixty-eight, 5-7.5-year-old children born at less than 32 weeks gestation were studied. Thirty-two pairs remained when refractive error, optic nerve abnormalities, manifest squint, cerebral palsy, mental retardation, brain damage (assessed by cerebral ultrasound), and retinopathy of prematurity were excluded. Relative to an age-matched comparison group, a significant number of these premature children demonstrated subtle impairments, such as color vision deficits and reduced contrast sensitivity in the mid to low spatial frequency range. These investigators highlighted the need for further studies to investigate the relationship between visual outcome and neonatal factors.

Goals of the Present Study

Earlier work in our laboratory has suggested that extremely-low-birthweight children are at high risk for experiencing problems with motion-defined form recognition

(Downie et al., 2003). Although the recognition of these kinetic shapes depends on global motion analysis, problems could arise at an earlier stage of motion processing, when local cues are being extracted. The goal of the first experiment of the proposed research was to assess the impact of premature birth on the development of sensitivity to first- and second-order local motion. No study to date has examined children born prematurely for vulnerability in these types of motion processing. Sensitivity was assessed through the determination of thresholds for detecting local motion of stimuli created through alternation of (a) darker and lighter bars that vary in luminance (first-order), or (b) higher or lower contrast bars of matched luminance (second-order). Threshold elevations for either type of local motion would be indicative of functional impairment in V1 (Adelson & Bergen, 1985; Mareschal & Baker, 1998, 1999; Van Santen & Sperling, 1984; Zhou & Baker, 1993). The goal of the second experiment was to determine whether VLBW children show impairments in the ability to detect coherent motion in broad-band, random-dot kinematograms. Elevation of coherence thresholds would be indicative of functional impairment in area MT (Newsome & Paré, 1988; Schenk & Zihl, 1997).

The sample of children recruited for the present experiments had, at most, experienced mild PVBD or ROP; a subset of the clinical sample had no history of either disorder. It was hypothesized that preterm children would be at increased risk for functional impairment on motion-processing tasks that require intact M pathway and/or intact dorsal stream functioning.

Method

Participants

An initial cohort of 126 children born between January 1, 1994 and April 1, 1998

were identified as potential candidates through the Newborn Follow-up Program at Children's Hospital in Winnipeg, Manitoba. This target group included very-low-birthweight children born at an appropriate weight for their gestational age, who were found to be free of significant developmental delays and major neurological abnormalities (i.e., mental retardation, blindness, deafness, cerebral palsy). Participation was limited to (a) children who showed no evidence of PVBD (as determined from neonatal cranial ultrasounds) or ROP (assessed through ophthalmological examination); and (b) those who had experienced only mild PVBD (Grade 1 or 2 intraventricular hemorrhage) and/or mild ROP (Stage 1 or 2) that had undergone spontaneous regression. Severity of ROP was coded along the four-point scale developed by the Committee for the Classification of Retinopathy of Prematurity (1984). Intraventricular hemorrhage classification was determined by the Papile classification system (Papile, Burstein, Burstein, & Koffler, 1978).

Of the initial cohort, the 74 families who lived within a 3-hr drive of our testing facilities in Winnipeg were invited to participate. Of the 28 responses received, five families were not interested in participating and one had moved out of the province. One of the remaining children was excluded based on a diagnosis of attention deficit hyperactivity disorder, and two on the basis of a diagnosis of pervasive developmental disorder. Thus, 19 participants remained (10 girls, 9 boys), with ages ranging from 62-101 months ($M = 82.0$, $SD = 11.7$ months). Of these, 8 children had no history of ROP or PVBD, 4 had experienced ROP that had undergone spontaneous regression, 6 had an ultrasound diagnosis of intraventricular hemorrhage, and 1 had a history of both ROP and intraventricular hemorrhage. With parental consent (see Appendix A), relevant

information about the preterm sample (e.g., birthweight, gestational age at birth, etc.) was obtained from medical records. Birthweights in the preterm group ranged from 732 g to 1483 g (M = 1198 g), and gestational ages ranged from 25 to 32 weeks (M = 29 weeks).

An age-matched group of 19 control children, born at term without medical complication or developmental problems, was recruited through local schools and day-care centers. The control children ranged in age from 59-107 months (M = 82.0, SD = 15.4 months). Information regarding birthweight and gestational age at birth was obtained from parents of the control sample through a questionnaire (see Appendix B). Birthweights in the control group ranged from 2983 g to 4457 g (M = 3525 g), and gestational ages ranged from 38 to 42 weeks (M = 40 weeks). Additional demographic information was gathered from all participating families.

The experimental protocol was approved by the Human Research Ethics board of the University of Manitoba. Informed consent for participation was obtained from parents of all children, and all parents received a debriefing form outlining possible visual problems that children may be susceptible to. (Appendix C).

Materials

Screening tests. The Peabody Picture Vocabulary Test – Third Edition (Dunn & Dunn, 1997) provided an estimate of verbal IQ. The visual screening battery included two tests of linear acuity: the Good-Lite Acuity Chart (Good-Lite Company) was used for 5- and 6-year-old participants, and the Lighthouse Acuity Chart (Lighthouse International) for 7- and 8-year-olds. Stereoacuity was assessed with the Titmus test (StereoOptical Company Inc.) and fusion with the Worth 4-dot fusion test (Bernell Company).

Tests of first- and second-order local motion sensitivity. The Infant Vision Studies

Laboratory at McMaster University supplied the stimuli for the tests of first-and second-order local motion sensitivity. Stimuli for this test were generated by a PowerMac G3 computer running Pixx 1.55 software, and were displayed on an Optiquest monitor, 32° wide by 24° high with a spatial resolution of 1024x768 pixels and a refresh rate of 75Hz. The monitor was calibrated using a Minolta LS-100 photometer and the stimuli were created with the calibration tool included in the Pixx software, according to the procedures summarized in Ellemberg et al. (2003).

All stimuli were made up of static two-dimensional random noise (referred to as the carrier), with binary luminance. Stimuli in the first-order local motion test consisted of luminance-modulated, alternating darker and lighter bars that made up 1 c/deg horizontal sine-wave gratings. The gratings drifted up or down for 1.5 s at a velocity of 6 deg/s and created the impression to the normal viewer of drift or movement. These gratings had an overall mean luminance of 37 cd/m^2, and subtended an angle of 10 deg wide x 10 deg high when viewed from a distance of 57 cm. The amplitude of the luminance modulation (Michelson contrast or depth modulation) was defined as:

depth modulation = (Lmax - Lmin) / (Lmax + Lmin)

where Lmax and Lmin are the maximum and minimum mean local luminance averaged over adjacent pairs of noise dots.

Stimuli used in the second-order local motion test were created by multiplying static two-dimensional random noise by a luminance-modulated sinusoidal grating. Detecting direction of motion in these stimuli (up vs. down) required discriminating

between alternating regions of higher and lower contrast bars while the mean luminance was held constant. The amplitude of the contrast modulation (depth modulation) was defined as:

depth modulation = (Cmax - Cmin) / (Cmax + Cmin).

where Cmax and Cmin are the maximum and minimum mean local contrasts (Michelson) in the stimulus.

During each of the two local motion tests, participants were also tested in a static condition to verify that the deficits observed were motion-specific. Here, they were asked to discriminate the orientation (horizontal vs. vertical) of grating patterns that were identical to the bars used in the dynamic conditions in terms of luminance and contrast, except that they were static rather than moving.

Test of global motion. The global motion stimulus (supplied by Infant Vision Studies Laboratory, McMaster University) consisted of an array of 300 black dots (luminance 4.7 cd/m^2) presented against a white background (luminance 98.3 cd/m^2). Each dot lived for one frame (13.3 ms) so the viewer could not detect the direction of motion by concentrating on any one dot. On any given trial, a certain percentage of the dots (signal) moved coherently among an array of randomly displaced dots (noise). In each successive frame, all signal dots were displaced in the same direction by .25 deg, giving the perception of continuous motion.

Procedure

Prior to testing, the procedures were explained and parental consent for

participation was obtained. Testing was conducted in a quiet room in the Duff Roblin Building at the University of Manitoba. All sessions were carried out with the child wearing optical correction, if required.

Prior to motion testing, acuity was assessed monocularly at 4 m using the Good-Lite Acuity Chart (5- and 6-year-olds) or the Lighthouse Acuity Chart (7- and 8-year-olds). The requisite acuity to pass the Good-Lite was 20/25 for 5-year-olds and 20/20 for six year olds. To pass the Lighthouse, 7- and 8-year-old children had to demonstrate acuity of 20/20. Testing of each eye was repeated with a 3+ dioptre add over the eye to rule out hypermetropia greater than 3 dioptres.

In the Titmus Test of stereoacuity, the child wore polarized lenses and pointed to the ring or animal on a given line that appeared to "jump out." Each symbol was created with disparate lines and the measure of stereoacuity was the minimum disparity that could be fused into a 3-D image. To demonstrate adequate stereoacuity, 6-, 7- and 8-year-olds had to correctly identify 3 of 3 animals and 9 of 9 rings (representing a stereoacuity of at least 40 sec of arc), and 5-year-olds were required to distinguish 3 of 3 animals and 5 of 9 rings (a stereoacuity of at least 100 sec of arc).

The Worth 4-dot fusion test assesses the child's ability to fuse the retinal images from the two eyes. In this test, the child wore filtered glasses (red/green), and looked at four dots (1 red, 2 green, 1 white) viewed from a distance of 33 cm directly in front of him/her. Adequate performance is evidenced when the child reports seeing 4 dots: 1 red, 2 green, and 1 of another colour (usually orange). This indicates that the child is able to fuse the images from both eyes and is not suppressing the image from either or both eyes.

Tests comprising the visual screening battery were interspersed with the tests of

local and global motion to combat fatigue. All motion tests were conducted in a dimly lit room and children were given 2 min to adjust to the testing conditions and room illumination. While completing the tests, children were positioned in a chin-rest to minimize movement artefacts. All motion tests were carried out with the eye of better acuity; in cases where acuity of the two eyes was equivalent, the tested eye was chosen at random. The untested eye was patched with 3M Micropore™ tape. The order of presentation of global motion and local motion tests was counterbalanced both between and within the sessions. During the motion tests the experimenter sat facing the child and entered responses on the keyboard while remaining naïve as to the direction of motion on test trials. Both verbal and hand gestures were accepted as responses, and in the case of a discrepancy, verbal clarification was required.

Local motion testing. Local motion testing began with the experimenter saying "We are going to play a game where you will see a grey box with moving stripes. Your job is to tell me if the stripes are moving up (experimenter points up) or moving down (experimenter points down)". To verify that the child understood the task, two trials of second-order motion were presented with feedback. To proceed, the child had to identify the direction of motion in 4 of 10 consecutive trials of second-order stimuli moving at 1.5 deg/s.

Static and motion trials for both first- and second-order stimuli were run in blocks, in a counterbalanced order. Testing in each block began with a practice trial administered under binocular viewing conditions. Discrimination thresholds were calculated for local motion stimuli using an ML-TEST staircase procedure (Harvey, 1986). Feedback was provided for the practice staircase only. For each participant, the

minimum amplitude modulation that produced accurate detection of motion direction 81% of the time was measured.

Global motion testing. Prior to commencement of global motion testing, participants were given instructions and demonstration trials under binocular viewing conditions. The experimenter began by presenting two trials at 100% coherence and two at trials at 50% coherence. The child then had to specify the direction of perceived motion in two practice trials at each of these levels of coherence, and was given contingent feedback. The instructions were as follows: "You will see a bunch of dots on the screen that will be moving either up or down. At first all the dots will be moving in the same direction, but soon there will be other dots trying to fool you. Your job is to tell me if most of the dots are moving up (experimenter points up) or down (experimenter points down)." The child began each trial fixating on a cross in the centre of the monitor.

Global motion coherence thresholds were measured using a 2-down, 1-up staircase procedure (Levitt, 1971). Feedback was given during an initial practice staircase completed under binocular conditions. During the monocular test staircase, no feedback was given, but children were praised for their effort. In the 2-down, 1-up staircase procedure, the dot coherence decreased after two successive correct responses, and increased after every incorrect response. The first decrease involved a step size of half an octave (from 100% to 50% coherence), and thereafter reversals changed by a step size of one quarter octave. After the first reversal, testing continued until eight reversals were completed. Coherence thresholds were measured using the mean coherence of the last six reversals. The coherence threshold referred to the minimum percentage of dots that must move in the same direction for the participant to detect the direction of motion accurately

71% of the time.

For 5- and 6-year-olds, the testing was split into two sessions with each session lasting approximately 1 hr (including adaptation and rest periods). Older children were able to complete the testing in one session with a 30 min break at the midpoint.

Results

All of the participants obtained scores on the test of verbal intelligence that fell within the normal range, ruling out the possibility that any deficits uncovered in other testing could be attributed to global cognitive impairment. Chi-squared analyses indicated that preterm children were matched with control children in terms of age at testing, mother's educational attainment, father's educational attainment, and family income. All control children passed the visual screening battery. Table I summarizes the results of the visual screening test for preterm children.

Data were not collected for two of the motion tests (first-order local motion and global motion) for two participants given that they were both unable to return for the second session. One of these participants was a control child and one was a preterm child.

Sensitivity to First- and Second-Order Local Motion

Static condition. Thresholds for detecting first- and second-order static stimuli were analyzed separately using independent t tests. Thresholds for preterm children were not significantly different than controls, both for the first-order condition [$t(34) = -1.025$, $p > 0.10$] and for the second-order condition [$t\ (36) = 0.485$, $p > 0.10$], indicating that the preterm children were able to perceive the first- and second-order properties normally when the patterns were stationary.

Local motion conditions. Independent t tests were conducted for both first- and

Table 1

Summary Table for Preterm Children on the Screening and Motion Processing Tests

Case#	Age	Screening	Status	Titmus	ROPTE	ROPOE	ATE	AOE	Worth 4-dot	FOM	SOM	Global
9	5	pass	normal	pass	0	0	20/20	20/20	pass	0.0027[a]	0.1429	0.2652
14	6	pass	normal	pass	0	0	20/20	20/20	pass	0.0005	0.0553	-0.0440
19	5	pass	pvbd[b]	pass	0	0	20/20	20/20	pass	-------	0.2842[a]	-------
8	5	pass	pvbd[b]	pass	0	0	20/20	20/20	pass	0.0310[a]	0.2800[a]	-0.3599
6	8	pass	pvbd[b]	pass	0	0	20/20	20/20 -1	pass	0.0099[a]	0.2395[a]	1.3002[a]
2	6	pass	rop[b]	pass	2[b]	2[b]	20/20	20/20	pass	-0.0009	0.0810	0.1862
15	8	fail[b]	normal	pass	0	0	20/20	20/25 -2[b]	pass	0.0002	0.0678	-0.2268
10	6	fail[b]	normal	fail[b]	0	0	20/20	20/20	fail[b]	0.0312[a]	0.2288[a]	0.0700
4	6	fail[b]	normal	fail[b]	0	0	20/20	20/20	pass	0.0001	0.01320[a]	1.1954[a]
5	7	fail[b]	normal	fail[b]	0	0	20/20	20/20	pass	0.0004	-0.0834	1.1202[a]
12	7	fail[b]	normal	fail[b]	0	0	20/20 -1	20/20 -2	pass	0.0061[a]	0.3045[a]	0.8334
16	8	fail[b]	normal	fail[b]	0	0	20/20 -1	20/20 -1	pass	-0.0005	0.1118	0.3358
7	5	fail[b]	pvbd[b]	fail[b]	0	0	20/20	20/20	pass	-0.0015	0.6832[a]	-0.2762
17	6	fail[b]	pvbd[b]	fail[b]	0	0	20/20 -1	20/30 -2[b]	pass	-----	-0.0626	------
3	8	fail[b]	pvbd[b]	fail[b]	0	0	20/20	20/20	pass	0.0096[a]	0.2487[a]	1.5619[a]
11	5	fail[b]	rop[b]	fail[b]	2[b]	2[b]	20/20	20/30 -2[b]	pass	0.0399[a]	0.3174[a]	0.4326[a]
18	6	fail[b]	rop[b]	fail[b]	0	1[b]	20/20	20/20 -1	pass	0.0002	-0.0120	-0.2449
13	7	fail[b]	rop[b]	fail[b]	0	1[b]	20/20	20/20	pass	0.0006	0.0161	0.8731[a]
1	7	fail[b]	rop/pvbd[b]	fail[b]	2[b]	1	20/20 -1	20/25 -2[b]	pass	0.0045[a]	0.0288	0.2578

Note: ROPTE = ROP tested eye; ROPOE = ROP other eye; ATE = acuity tested eye; AOE = acuity other eye. FOM, SOM and Global values are deficit scores. Case 19's matched control and case 17 were not tested with FOM or Global stimuli.

[a]Threshold score falling more than 2 standard deviations above the control mean. [b]Abnormal screening test

second-order local motion to determine if there were significant differences between the mean thresholds for preterm and control children. Preterm children had significantly higher mean thresholds than the control children for both first-order local motion [Welch's t (34) = 2.632, $p< 0.05$] and second-order local motion [Welch's t (36) = 3.652, $p < 0.01$]. Overall, the mean threshold for discrimination of direction of first-order motion was 2% higher among premature children than controls; for second-order motion, preterm children's mean thresholds were 48% higher than controls'. With each type of stimulus, thresholds in nine of the preterm children were more than two standard deviations above the control mean. In seven cases, these clinically significant impairments were evident with both types of local motion. Interestingly, two children (cases 1 and 9) showed an isolated first-order motion processing deficit, and one (case 7) showed an isolated second-order motion processing deficit.

Age-at-test was not significantly correlated with sensitivity to either type of motion in the sample of control children (see Figures 1A and 2A). Their performance had, essentially, reached stable levels. Threshold scores were more variable in preterm children than in controls, and tended to show improvement with increasing age (Figures 2A and 2B). This trend was significant for second-order motion ($r = -.50$, $p < .05$).

Global Motion Condition

Preterm children had coherence thresholds that were considerably more variable and three times higher, on average, than controls (see Figure 3). A Welch's t-statistic demonstrated that the group difference was significant, $t(34) = 2.70$, $p < 0.05$. Further analysis revealed a significant negative correlation between age and performance on the task for control children ($r = - 0.572$, $p <0.05$), but not for preterm children ($r = 0.216$,

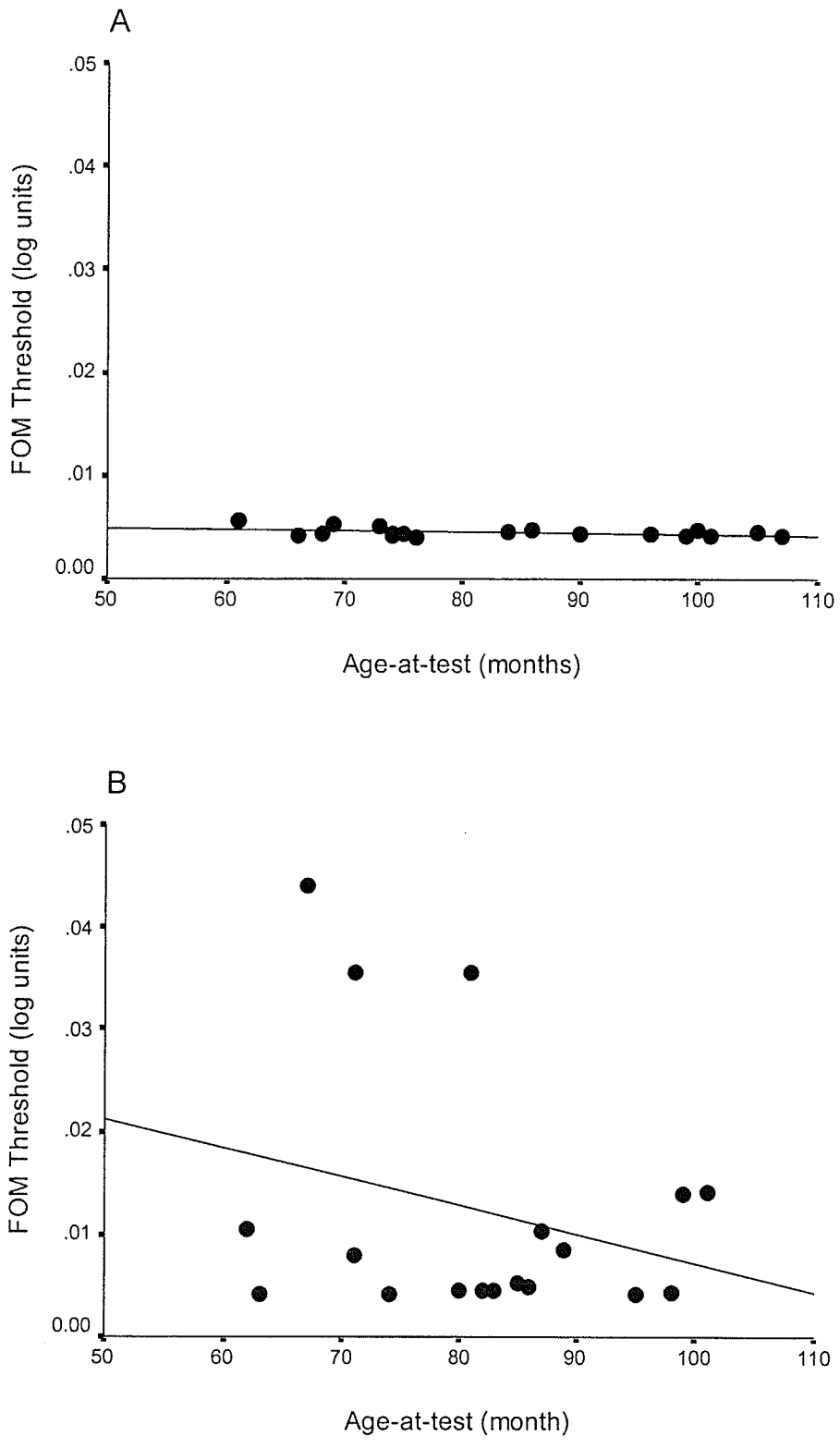

Figure 1. First-order motion thresholds as a function of age at testing. Panel A=control children; Panel B=preterm children

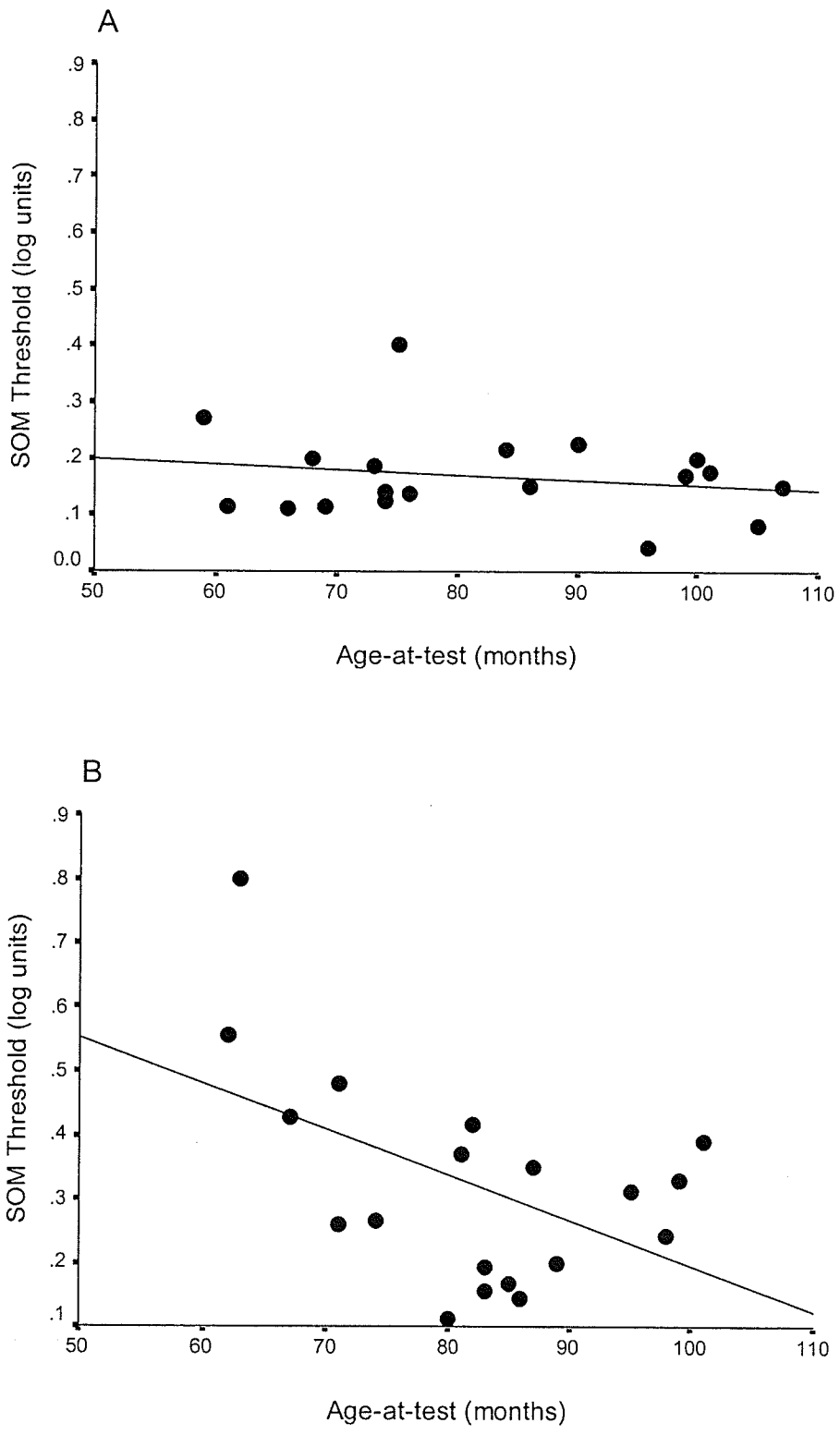

Figure 2. Second-order motion threshold as a function of age-at-testing. Panel A = control children; Panel B = premature children.

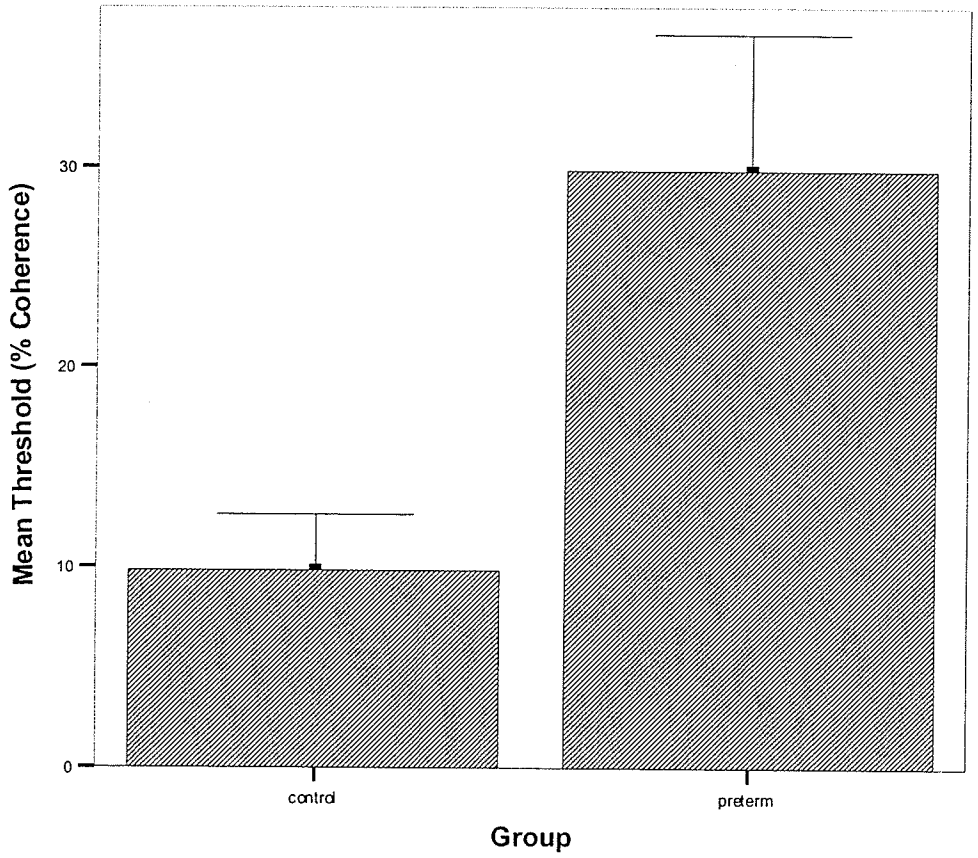

Figure 3. Global motion coherence thresholds for the preterm and control groups.

$p = 0.390$). Thus, only control children's performance on the task showed improvement with age (see Figures 4A and 4B). Two premature children (cases 5 and 13) showed an isolated global motion-processing deficit.

Deficit Scores

Deficit scores were computed for each premature child to reflect that child's level of performance on each of the tests of motion processing, relative to controls. In calculating each of these scores, the premature and control children were arranged in order from youngest to oldest. Pairs were created by matching the youngest premature child with the youngest control, and so on. The difference between the ages ranged from -10 to +7 months ($M = 1.5$ week). Deficit scores were calculated for each type of motion by taking each individual premature child's log threshold score and subtracting their age-matched control child's log threshold score. These scores were entered into a Friedman test for related samples. This test was significant, $\chi^2 = 8.941$, $p < .05$, and follow-up tests using the Wilcoxon signed ranks test showed that deficit scores were larger for the more computationally complex types of motion processing (second-order local and global) than for first-order motion processing. Mean deficit scores for the premature children were 0.0079 log units for first-order local motion, 0.160 log units for second-order local motion, and 0.428 log units for global motion (see Figure 5).

The Relationship Between Motion Processing and Stereoacuity

The results of the visual screening revealed that 12 of the 19 preterm children (63%) failed the Titmus Test of Stereoacuity (see Table 1). To examine the relationship between performance on this test and motion processing abilities, the preterm group was subdivided into two groups (Passed Titmus, Failed Titmus) whose performance on each

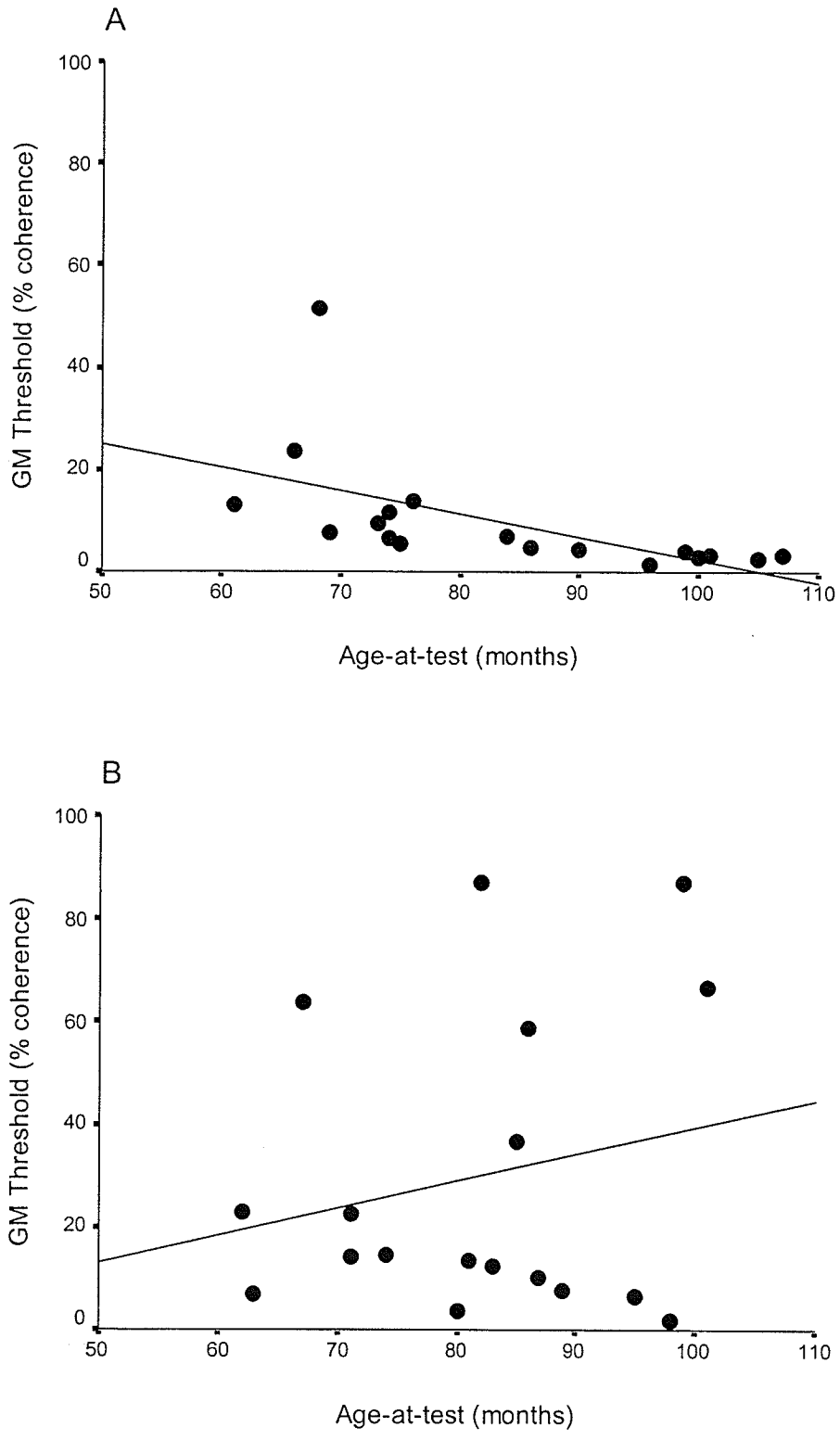

Figure 4. Global motion threshold as a function of age-at-testing. Panel A = control children; Panel B = premature children.

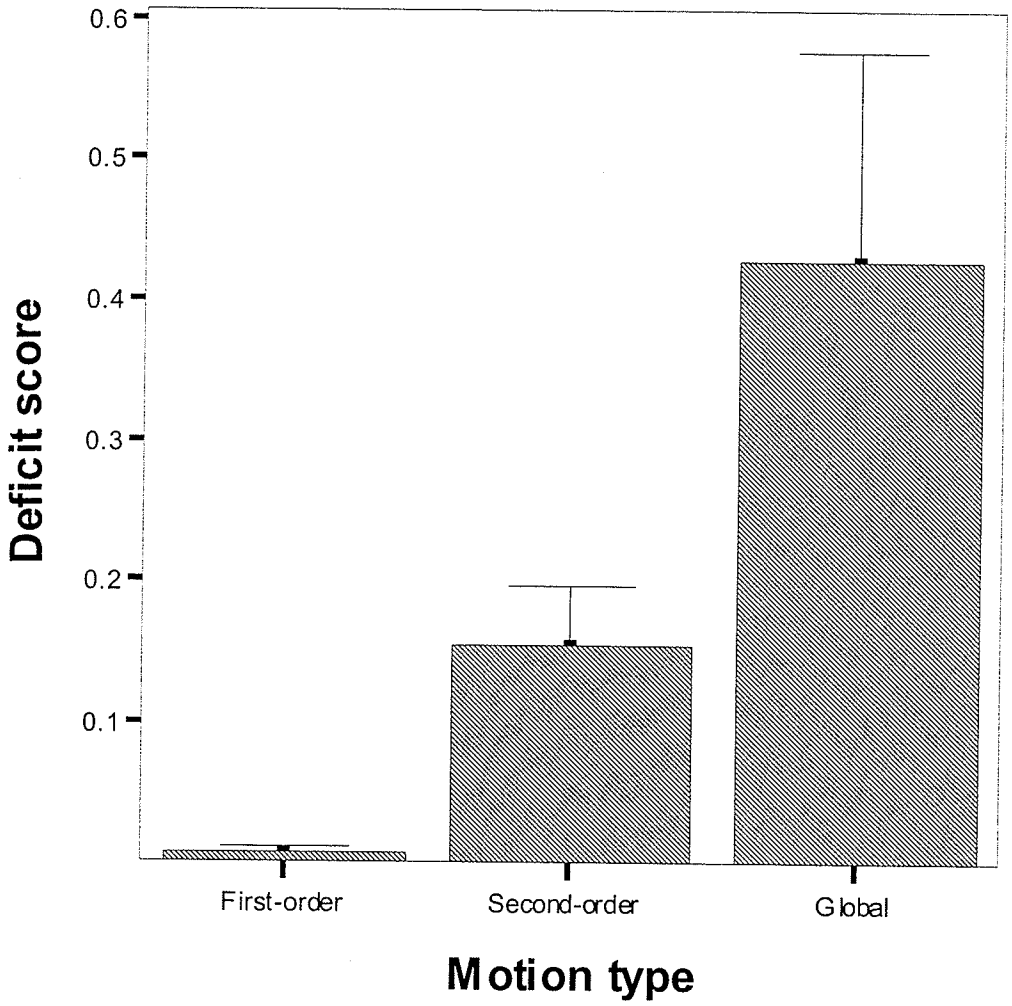

Figure 5. Deficit scores seen with different types of motion analysis (premature children only).

of the motion processing tasks was compared to that of full-term controls with separate Welch's F-tests. This analysis revealed that, on all three of the motion tests used in the present study, preterm children who passed the Titmus had thresholds that were statistically equivalent to those who failed. Inspection of Table 1, moreover, reveals that, for each type of motion, several of the children with the lowest deficit scores (i.e. whose performance was most like that of full-term controls, e.g., cases 16 and 18) were children who had failed the Titmus test.

The Relationship Between Motion Processing and ROP/PVBD Status

Some of the preterm children in the present sample had experienced either mild PVBD and/or mild ROP that had undergone spontaneous regression. Due to the limited sample size, it was not possible to subdivide the preterm sample along these lines to make statistical comparisons. Three of five children affected by ROP were impaired in their motion processing, while all of the children with PVBD for whom complete data were available showed impaired performance on at least one of the motion tests. It is worth noting, however, that five of eight preterm children with no history of PVBD or ROP were also impaired on at least one of the tasks. In one of these cases (9) no impairments were detected in the visual screening.

Discussion

The most striking finding in the present study was that premature children were impaired, relative to age-matched controls, on first-order, second-order and global motion processing. These deficits were motion-specific; they could not be reduced to deficits in processing luminance or contrast, given that impairments were not evident in the static conditions. Nor could problems with stereoacuity, which affected 63% of the preterm

sample, explain their difficulties in motion analysis because there was no relationship between performance on the stereoacuity task and on tests of motion processing.

Control children showed no significant age-related changes in sensitivity to first- and second-order motion, although their performance did appear to be more variable with second-order motion. In stark contrast to controls, preterm children showed a clear age-related improvement (a decline in threshold scores) for second-order motion. Earlier work has suggested that this type of motion analysis matures more slowly than first-order motion processing (Ellemberg et al., 2003). What we may be observing, then, is a delay that shows improvement with time, rather than a persistent deficit, on these tests. Additional studies using older samples of premature children may shed light on this issue.

Sensitivity to global motion showed age-related improvement in control children. This is consistent with the results of another recent study in which coherence thresholds were not found to reach adult levels until children were 10-11 years of age (Gunn et al., 2002). In the present study, the performance of the preterm children was much more variable than controls' and showed no clear improvement with age. Since analysis of these types of stimuli is believed to involve area MT (Newsome & Paré, 1988; Schenk & Zihl, 1997), these results would be consistent with dysfunction in this region. Pronounced deficits in global motion processing have also been reported in extremely-low-birthweight children by Downie et al. (2003). Their task, however, involved motion-defined form recognition, which likely depends on the integrity of area KO – an extrastriate region that receives a strong input from MT (Van Oostende et al., 1997).

An examination of the individual performance of the preterm children participating in the present study revealed a triple dissociation. Thus, cases were found

showing isolated impairments only in the perception of first-order local motion, only in the perception of second-order local motion, or only in the perception of global motion. These findings complement other recent reports showing dissociations between the processing of first- and second-order cues (Vaina, Cowey & Kennedy, 1999) and between local and global processing (Giaschi, Regan,, Kothe, Hong, & Sharpe, 1992). The fact that these dissociations can occur suggests that each type of motion processing involves different mechanisms. It also suggests that deficits in global motion analysis do not simply stem from problems in discerning local cues.

Among preterm children, deficits were smallest on the test requiring extraction of first-order motion cues. It has been suggested (e.g., Ellemberg et al., 2003) that this type of motion analysis involves fewer processing steps than are involved in the extraction of second-order or global motion cues. The present findings suggest that deficits in visual motion analysis become magnified in preterm children as the complexity of the underlying computations increases.

The small sample size in the present study made it impossible to compare statistically the impact of mild PVBD and ROP on visual development. Nonetheless, three of the five preterm children with mild ROP and all of the preterm children with mild PVBD for whom complete data were available showed impaired performance on at least one of the motion tests. It is worth noting, however, that five of eight preterm children with no history of either PVBD or ROP were also impaired on at least one of the tasks. In one of these cases no other impairments were detected in the visual screening battery. Although it is possible that cranial ultrasounds and standard ophthalmological examinations were simply unable to detect subtle forms of pathology in these children, it

is also possible that the atypical visual experiences associated with their preterm birth interfered with the normal development of their motion processing systems (cf. Dowdeswell et al., 1995). Certainly, ocular deprivation due to congenital cataracts is associated with abnormal development of sensitivity to luminance- and contrast-defined local motion (Lewis, Ellemberg, Maurer, Defina & Brent, 2000), and global motion (Ellemberg, Lewis, Maurer, Brar, & Brent, 2002).

Developmental rate, early visual deprivation, and prematurity may not affect all aspects of vision in the same way. In patients with congenital cataracts, deficits in temporal vision are only apparent at low temporal frequencies, and are not as severe as deficits in spatial vision (Ellemberg, Lewis, Maurer, Lui & Brent, 1999). Since temporal vision matures more quickly than spatial vision, these findings are consistent with the theory that late-maturing aspects of vision are particularly vulnerable to ocular deprivation (Maurer & Lewis, 1993). It would be interesting in future studies to compare the development of spatial and temporal vision in VLBW children with no known ocular or cerebral pathology. Dowdeswell et al. (1995) has suggested that such children show reduced colour vision when compared to a group of control children. The authors suggest that early exposure to certain wavelengths may permanently deplete the number of cones. This class of photoreceptors, of course, plays a key role in spatial vision.

The present finding that the majority of the preterm children (63%) failed the stereoacuity test merits some discussion. These findings are similar to the results of previous studies where stereoacuity was tested in premature children. For example, Dowdeswell et al. (1995) found that 37% of the premature children with no known ocular or cerebral pathology had steroacuities worse than 170 seconds of arc, compared with

only 7% of the control children. Of those preterm children, 19% had no stereoscopic vision compared to none of the control group. Similarly, Jongmans et al. (1996) found that preterm children had abnormal stereopsis, and that this was significantly associated with poor performance on tests of perceptual-motor abilities. Exploring possible relationships between performance on tests of motion processing, stereopsis and visuomotor skill will be of particular importance in the future. Poor visuomotor function will impact on many academic and athletic skills, which in turn can affect social development. It is, therefore, important for researchers and clinicians to understand the basis of these problems, so that effective interventions can be designed and implemented.

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Appendix A
Research Consent Form
(Clinical Samples)

TITLE OF PROJECT: Neural Mechanisms of Visual Motion Processing
Principal Investigator: Dr. Lorna Jakobson, Department of Psychology, University of Manitoba
Collaborator: Dr. Oscar Casiro, Newborn Follow-up Program, Children's Hospital

PURPOSE OF THE RESEARCH
Children who were born too soon and/or very small sometimes have more trouble with their vision than children who were born at or near their due date. We are trying to find out why they have these difficulties, and how we can help them to develop their visual skills. To do this, we need to compare their test results to those of a control group of children, born at full term, weighing more than 5.5lbs (2.5kg) in order to determine which tests are more difficult for the premature children. Your child is being asked to participate as a member of the group of premature children.

DESCRIPTION OF THE RESEARCH
Your child will be asked to perform a number of school-like activities, such as answering questions, looking at pictures, and identifying letters. Your child will then be required to make some judgements about the movement of lines or dots presented on a computer screen. Your child may find most of these activities quite fun, and none of them take very long. We will provide your child with breaks when necessary throughout the testing, so that he/she doesn't become too tired.

POTENTIAL HARMS
There are no known harms associated with participation in this study. However, some of the children may find some of the tests boring or a little bit hard to do.

POTENTIAL BENEFITS
(a) If we can figure out why many premature/small-for-gestational age children have difficulty using vision to follow movement, we may be able to think of better ways to help them develop this skill.
(b) Although we think that the ability to use vision to follow movement is important for the development of other skills like reading and writing, we don't know this for sure. It may be that, in the future, tests of motion vision will help us to identify preschool children at risk for going on to have problems in these areas.
(c) The information we gather in this study, although strictly experimental, can be shared with your child's doctor if you wish. To do this, we would require your signed consent.

CONFIDENTIALITY
Only aggregate scores of the children in the two groups included in this study (premature and control groups) will be discussed in any presentations of the results. To complete our study, however, we will need your permission to access pertinent information from your child's neonatal medical records. Your family's confidentiality will be respected at all times, and no information that discloses the identity of your child will be released or published without consent unless required by law. For your information, the research consent form and data will be stored in a secure place. The results of the tests described above will be used for research purposes only in the context of this study. We would need

your permission and signed consent to send these test scores to another professional.

PARTICIPATION

Participation in this research is entirely voluntary. If you choose not to participate, you and our family will continue to have access to quality medical care. There are no penalties for choosing not to participate, and if you choose on behalf of your child to participate in this study, you can withdraw your child from the study at any time.

CONSENT

I acknowledge that the research procedures described above have been explained to me and that any questions that I may have asked have been answered to my satisfaction. I have been informed of the alternatives to participation in this study, including the right not to participate and the right to withdraw without compromising the quality of medical care for my child and for other members of my family. As well, the potential harms and discomforts have been explained to me, and I also understand the benefits of participating in this research study. I know that I may ask now, or in the future, any questions I have about the study or the research procedures. I have been assured that records relating to my child and my child's care will be kept confidential and that no information will be released or printed that could disclose personal identity without my permission unless required by law.

I hereby consent for my child _____ to participate. I also consent to the disclosure of pertinent information from my child's medical records, regarding: date of birth, gestational age at birth, birthweight, status regarding retinopathy of prematurity or other ocular problems, duration of mechanical ventilation and treatment with supplemental oxygen, treatment with steroids/dexamethasone, results of cranial imaging or other testing done to assess neurological function.

Name of child:_____ Date of birth (d/m/y):_____

Name of parent or legal guardian:_____

Signature and capacity (e.g., parent):_____

Date of consent:_____

Name of person who obtained consent:_____

Signature: _____

Questions or concerns regarding this research project should be directed to **Dr. Lorna Jakobson** of the Department of Psychology, University of Manitoba. She may be reached at telephone number **(204)-474-6490**. If, after speaking to Dr. Jakobson, some questions/concerns remain, you should contact **Dr. Gerry Sande**, Head of the Department of Psychology, University of Manitoba, at **(204)-474-9360**.

Research Consent Form
(Controls)

TITLE OF PROJECT: Neural Mechanisms of Visual Motion Processing
Principal Investigator: Dr. Lorna Jakobson
Collaborator: Dr. Oscar Casiro, Newborn Follow-up Program, Children's Hospital

PURPOSE OF THE RESEARCH
Children who were born too soon and/or very small often have more trouble with their vision than children who were born at or near their due date We are trying to find out why they have these difficulties, and how we can help them to develop their visual skills. To do this, we need to compare their test results to those of a control group of children, born at full term, weighing more than 5.5lbs (2.5kg) in order to determine which tests are more difficult for the premature children. Your child is being asked to participate as a member of the control group.

DESCRIPTION OF THE RESEARCH
Your child will be asked to perform a number of school-like activities, such as answering questions, looking at pictures, and identifying letters. Your child will then be required to make some judgements about the movement of lines or dots presented on a computer screen. Your child may find most of these activities quite fun, and none of them take very long. We will provide your child with breaks when necessary throughout the testing, so that he/she doesn't become too tired.

POTENTIAL HARMS
There are no known harms associated with participation in this study. However, some of the children may find some of the tests boring or a little bit hard to do.

POTENTIAL BENEFITS
(a) If we can figure out why many premature/small-for-gestational age children have difficulty using vision to follow movement, we may be able to think of better ways to help them develop this skill.
(b) Although we think that the ability to use vision to follow movement is important for the development of other skills like reading and writing, we don't know this for sure. It may be that, in the future, tests of motion vision will help us to identify preschool children at risk for going on to have problems in these areas.

CONFIDENTIALITY
Only aggregate scores of the children in the two groups included in this study (premature and control groups) will be discussed in any presentations of the results. Your family's confidentiality will be respected at all times, and no information that discloses the identity of your child will be released or published without consent unless required by law. For your information, the research consent form and data will be stored in a secure place. The results of the tests described above will be used for research purposes only in the context of this study. We would need your permission and signed consent to send these test scores to another professional.

PARTICIPATION

Participation in this research is entirely voluntary. There are no penalties for choosing not to participate, and if you choose on behalf of your child to participate in this study, you can withdraw your child from the study at any time.

CONSENT

I acknowledge that the research procedures described above have been explained to me and that any questions that I may have asked have been answered to my satisfaction. I have been informed of the alternatives to participation in this study, including the right not to participate and the right to withdraw without penalty for my child and for other members of my family. As well, the potential harms and discomforts have been explained to me, and I also understand the benefits of participating in this research study. I know that I may ask now, or in the future, any questions I have about the study or the research procedures. I have been assured that records relating to my child will be kept confidential and that no information will be released or printed that could disclose personal identity without my permission unless required by law.

I hereby consent for my child _____ to participate.

Name of child:_____ Date of birth (d/m/y):_____

Name of parent or legal guardian:_____

Signature and capacity (e.g., parent):_____

Date of consent:_____

Name of person who obtained consent: _____

Signature: _____

Questions or concerns regarding this research project should be directed to **Dr. Lorna Jakobson** of the Department of Psychology, University of Manitoba. She may be reached at telephone number **(204)-474-6490**. If, after speaking to Dr. Jakobson, some questions/concerns remain, you should contact **Dr. Gerry Sande**, Head of the Department of Psychology, University of Manitoba, at **(204)-474-9360**.

Appendix B

Background Information

This information will be kept strictly confidential and will be used for research purposes only.

Mother

Racial background

(please specify):_____

In which country were you raised?

_____

Your date of birth:_____

Age when your child was born:_____

Number of Brothers:_____ Number of sisters:_____

Please indicate the highest level of education that you have completed:

____ Less than seventh grade

____ Seventh through ninth grade

____ Tenth through eleventh grade

____ Completed high school

____ Partial college/university (at least one year) or specialized training

____ Completed college or university degree

____ Completed graduate degree

Please indicate which diploma(s), degree(s), or certificate(s) you have received:

____ None

____ HS diploma/GED

____ Associate degree

____ BA or BSc

____ MA or MSc

____ MD, DDS, JD, LLB, or LLD

____ PhD or EdD

____ Certificate(specify):_____

Where did you study if not in Canada?

_____

Present Occupation:

What kind of work do you do now?

_____

What kind of business or industry is this?

_____

What are your most important duties or activities?

_____

What is your job title?

_____

How much leave (if any) were you able to take when your son/daughter came home?_____

Present marital status:

____ married ____ divorced/separated ____ common-law

____ widowed ____ single

Father

Racial background (please specify):

_____

In which country were you raised?

_____

Your date of birth:_____

Age when your child was born:_____

Number of Brothers:_____ Number of sisters:_____

Please indicate the highest level of education that you have completed:

____ Less than seventh grade

____ Seventh through ninth grade

____ Tenth through eleventh grade

____ Completed high school

____ Partial college/university (at least one year) or specialized training

____ Completed college or university degree

____ Completed graduate degree

Please indicate which diploma(s), degree(s), or certificate(s) you have received:

____ None

____ HS diploma/GED

____ Associate degree

____ BA or BSc

____ MA or MSc

____ MD, DDS, JD, LLB, or LLD

____ PhD or EdD

____ Certificate

(specify):_____

Where did you study if not in Canada?

_____

Present Occupation:

What kind of work do you do now?

_____

What kind of business or industry is this?

_____

What are your most important duties or activities?

_____

What is your job title?_____

How much leave (if any) were you able to take when your son/daughter came home?_____

Present marital status:

____ married ____ divorced/separated __ common-law

____ widowed ____ single

Family

Please indicate who your child lives with:

____ Mother ____ Both Parents

____ Father ____ Other (please specify):_____

How many people are presently living in the home with your child?

_____

Please indicate your annual household income:

____ Under $11,000 ____ $31,000-$40,999 ____ > $75,000

____ $11,000-$20,999 ____ $41,000-$50,999

____ $21,000-$30,999 ____ $51,000-$75,000

What language(s) are spoken at home?_____

What language(s) do you speak with your child? _____

Have either parent ever had any academic problems? If yes, whom and what type?_____

_____

Children

Child's date of birth: _____Birth weight:_____ Gestational age: _____

Were there any problems during pregnancy or delivery? If yes, please describe:

_____

_____

_____

_____

Has your child ever sustained a head injury? If yes, please describe:

_____

_____

_____

_____

How long was he/she unconscious for?

_____

Please indicate any of the following services that your child has used and for what reason. Occupational Therapist, Physical Therapist, Speech Therapist, Dietician, Psychologist, Psychiatrist, Social Worker, Infant Development, Worker/Infant Stimulation Worker, or any special services:

_____

_____

_____

_____

_____

How many other children do you have now? Boys _____ Girls _____

Have any of your children been identified as having behavioral difficulties? If yes, whom and what type?

_____

_____

_____

_____

May we contact you for further details if necessary? _____ Phone #:_____

Appendix C
Parent Information Sheet (Preterm Sample)

Dear Parent,

Thank you for your willingness to participate in this research.

This letter is intended to give you information about visual problems that are sometimes associated with premature birth. While it is quite possible that none of these problems will affect your child, it is important for parents of children born prematurely to be aware of them, to have their children's vision checked regularly, and to contact their eye doctor if concerns arise. Some children born prematurely have one or more of the following problems:

- Crossed eyes (strabismus). This condition is sometimes associated with problems with depth perception or peripheral vision
- Lazy eye or amblyopia. Sometimes one eye is not as strong as the other and it may tend to wander or stare into space when your child is tired or distracted.
- Eyes that jump, dance, wiggle or oscillate back and forth are caused by a condition called nystagmus, the cause of which is unknown.
- Near-sightedness (myopia)

In addition to these problems, which affect the eyes themselves, some children born prematurely find it difficult to use visual information to learn about the spatial layout of the world, or to guide their movements. This can lead to problems learning motor skills like catching a ball, drawing or coloring within the lines, or printing. If a child has problems moving their eyes (or keeping them still) this can interfere with learning to read. The research project that your child participated in today was designed to allow us to get a better understanding of the precise nature of the visual problems that contribute to difficulties in these areas. We hope that by doing this kind of research we will be able, in future, to develop better ways to help children overcome their visual problems.

Many thanks, again, for your time and cooperation. Your family's contribution to our research is appreciated.

Parent Information Sheet (Control Sample)

Dear Parent,

Thank you for your willingness to participate in this research.

This letter is intended to give you information about some of the visual problems that children may experience. While it is unlikely that any of these problems will affect your child, it is important for parents to be aware of them, to have their children's vision checked regularly, and to contact their eye doctor if concerns arise. Some children may show signs of:

- Crossed eyes (strabismus). This condition is sometimes associated with problems with depth perception or peripheral vision
- Lazy eye or amblyopia. Sometimes one eye is not as strong as the other and it may tend to wander or stare into space when your child is tired or distracted.
- Eyes that jump, dance, wiggle or oscillate back and forth are caused by a condition called nystagmus, the cause of which is unknown.
- Near-sightedness (myopia)

Children born prematurely are at a greater risk for these visual problems. The research project that your child participated in today was designed to allow us to get a better understanding of the precise nature of the visual problems that children born prematurely often exhibit. We hope that by doing this kind of research we will be able, in future, to develop better ways to help children overcome their visual problems.

Many thanks, again, for your time and cooperation. Your family's contribution to our research is appreciated.