The study was designed to consider the possible relationship between the development and integration of the body-righting reaction and the development of manual midline crossing behavior in learning-disabled and normal children aged 6 to 8 years (23 subjects in each group). A combination of three movement patterns (rolling from supine to prone, transition from supine to standing, and equilibrium in sitting) was used to analyze the body-righting reaction. The Space Visualization Contralateral Use (SVGU) score derived from the Southern California Space Visualization Test was used to measure manual midline crossing behavior. Results of the study found that the learning-disabled subjects exhibited significantly reduced performance on both test measures, when compared to the normal controls. A correlation between scores on the two tests did not reach significance. The findings are described as they relate to sensory integration testing, and the need for further study of the body-righting reaction and manual midline crossing behavior.

Behaviors characterizing ontogenetic development comprise a complex interweaving of predetermined biological-neurological factors that the individual adapts to the demands of the environment (1). This theory, proposed by Gilfoyle and Grady (1), depicted postural reflex maturation and the development of adaptive motor responses as interrelated factors—maturation in one area facilitating maturation in the other. If this theory is correct and an interrelationship between developing behaviors...
Review of the Literature

The body-righting reaction appears within the rolling response in infancy, and is seen initially as simultaneous rotation of the head, trunk, and pelvis in response to head turning (the neck-righting reflex). It matures into segmental rolling (the body-righting reaction acting on the body), where rotation of the head or any one of several body parts results in derotation of the remaining body segments (1, 4, 5). The appearance of trunk rotation and counter-rotation patterns is thought to stimulate development of the diagonal trunk musculature (external and internal oblique, latissimus dorsi, etc.), which assists in maintaining midline trunk stability (1, 6). Thus, it serves as a stimulus for the development of differentiation between limb and body segments and allows for the combining of complex patterns of flexion, extension, and rotation into the development of basic stability and mobility patterns (creeping, walking, etc.) and skilled adaptive motor responses (1, 4, 6).

Manual midline behavior is thought to mature in conjunction with the development of visually guided hand movements in infancy (7, 8). This process begins with unilateral hand movements that become oriented toward the midline by 3½ months of age (8). A series of changes in midline orientation of the hands ensues. Unilateral hand movements are replaced by unilateral and bilateral hand play at midline (8). This is followed by a bilateral midline approach toward objects that frequently results in supine to prone rolling if the objects are out of reach (7). A return to unilateral hand use (reaching with one hand while holding an object in the other) is seen next (8). This is followed by a return to unilateral and bilateral midline play (transfer and matching of objects at midline) (9). Crossing the body midline to approach or grasp objects has been elicited through the use of physical restraint in infants as young as 4½ to 5 months (10). The age at which spontaneous midline crossing behavior emerges in infancy or early childhood has not been reported. However, since physical restraint maximizes the possibility of eliciting contralateral hand use, it may be logical to assume that the appearance of spontaneous manual midline crossing occurs at a later age than that cited by Provine and Westerman. Research suggests that the frequency of spontaneous manual midline crossing increases with chronological age within the 4 to 8-year-age range, an increase that has been identified as possibly being related to the development of handedness (11, 12). The development of manual midline behavior has also been described as contributing to early ego development and to the development of body scheme (laterality and directional-ity) (7, 13).

Evidence of a possible relationship between the development of the body-righting reaction and manual midline behavior can be found within postural reflex development. The emergence of both behaviors is said to occur at 3½ to 4 months of age with the visual disappearance of the Asymmetrical Tonic Neck Reflex (ATNR) (7, 14). The asymmetrical tonus changes produced by the ATNR, paired with spinal extension from the Tonic Labyrinthine Reflex (TLR), are thought to be responsible for the initial appearance of the body-righting reaction (the neck-righting reflex) (1, 15). Reduction in the influence of the ATNR allows for the freedom of arm movement needed to bring the hands toward midline when in supine (onset of manual midline behavior) (7). By 5 months of age, attempts at bilaterally engaging objects placed out of reach frequently result in the infant rolling from supine to prone (8). Repetition of the rolling response is said to assist in integration of the ATNR and TLR (1).
Bringing the hands toward midline is thought to help initiate the rolling response, with repetition of the maneuver stimulating the emergence of segmental rolling; it allows the infant to begin the rotation pattern with the upper extremities while using lower extremity extension to push off the supporting surface and into prone (1). The reflexive character of the rolling response gradually diminishes as it matures from an awkward to a smoothly coordinated segmental rolling response (16). Thus, a process has been described in which the ATNR and TLR both initiate and are dependent on the development of the body-righting reaction for their integration, a process in which manual midline behavior appears to make a contribution.

Although evidence of overlap and possible interdependence between the development of manual midline crossing behavior and the body-righting reaction is not described in the literature, theoretical support for such an interrelationship can be identified. The rotation and counterrotation patterns, which become integral components of the mature righting and equilibrium reactions, are also thought to allow for the flexibility in trunk rotation needed for the development of skilled adaptive motor responses (1). Midline crossing behavior has been described as hand movements that cross the body midline. Although it may be possible to cross the body midline to engage objects placed within easy reach without rotating the trunk around the center body axis, it is logical to assume that skilled prehension and grasping objects placed beyond arm’s length would require either trunk rotation or gross postural adjustments for their execution. Both such behaviors, a lack of flexibility in trunk rotation and a tendency to use gross postural adjustments to avoid midline crossing, have been reportedly observed in learning-disabled children labeled as having midline deficits (2). This lack of flexibility in trunk rotation associated with midline avoidance has been described by Ayres (2) as potentially related to inadequate development and integration of the body-righting reaction. These clinical observations also may have contributed to Murrey’s (17) hypothesis that diminished midline crossing behavior and inadequate development and integration of the body-righting reaction may be related findings.

In spite of the frequent finding of a co-existence of deficits in development and integration of the body-righting reaction and in the development of manual midline crossing behavior, direct analysis of the possible relationship between these developmental factors has not been undertaken. However, support for such a study can be found in the continuing need for refinement in the differential diagnosis of children with sensory integrative dysfunction. Knowledge of such a relationship might also help in designing effective treatment strategies for use with those children showing coexisting deficits. The present study was prepared to analyze this possible relationship between the development and integration of the body-righting reaction and the development of manual midline crossing behavior. It was designed to determine whether 6- to 8-year-old learning-disabled children exhibit a reduction in development and integration of the body-righting reaction and a reduction in frequency of manual midline crossing behavior when compared to matched controls, and whether a correlation between these behaviors exists within the learning-disabled and normal control groups.

**Method**

**Subjects:** The research sample contained 46 children 6 to 8 years of age attending one of three public elementary schools in rural-suburban Peoria, Illinois. The children, predominately white, came from a variety of socioeconomic backgrounds. The sample consisted of two groups, a learning-disabled group (n = 23) and a normal control group (n = 23). Each group included 10 girls and 13 boys. All children were identified by school personnel as having normal intelligence (IQ ≥ 85) and having no history of hard neurological signs, orthopedic problems, or emotional disturbance. Children in the learning-disabled group were diagnosed by using routine school diagnostic procedures (test measures included the Peabody Individual Achievement Test, Wide Range Achievement Test, Illinois Test of Psycholinguistic Abilities, etc.) and were receiving special education services at the time of data collection. The children in the control group were matched by sex and chronological age (within 6 months) with those in the learning-disabled group (see Table 1). They were performing adequately (within 6 months of grade level) in all academic subjects and had no history of receiving remedial or special education services.

**Procedure.** Two test measures were used. The Space Visualization Contralateral Use (SVCU) score was used to measure the frequency of manual midline crossing. The SVCU score is a ratio of contralateral to ipsilateral hand use derived through tabulation of hand preference observed during administration of the Space Visualization Test.
Table 1
Ages for Learning-Disabled and Control Group Subjects

<table>
<thead>
<tr>
<th>Sample Groups</th>
<th>Learning-Disabled</th>
<th>Normal Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male (n = 13)</td>
<td>Male (n = 13)</td>
</tr>
<tr>
<td></td>
<td>Female (n = 10)</td>
<td>Female (n = 10)</td>
</tr>
<tr>
<td>Age (in months)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>88.0</td>
<td>86.5</td>
</tr>
<tr>
<td>S.D.</td>
<td>7.1</td>
<td>4.9</td>
</tr>
<tr>
<td>Range</td>
<td>72-93</td>
<td>75-96</td>
</tr>
</tbody>
</table>

of the Southern California Sensory Integration Tests (18). Development and integration of the body-righting reaction was measured by observational analysis of three movement patterns: rolling from supine to prone, transition from supine to standing, and equilibrium in sitting. Development of these tests was based primarily on the works of Bobath (4), McGraw (16), and Scheltenbrand (19). Testing was completed during a single 20-minute session for each subject, with the two test measures (Space Visualization Test and combined body-righting assessments) presented in counter-balanced order. All test administration was performed by a single examiner, who was certified in administration and interpretation of the Southern California Sensory Integration Tests.

The Space Visualization Test was administered in the standardized manner (20) and the SVCU score was computed as described by Ayres (18). Simultaneous use of right and left hands during block manipulation did not enter into the scoring procedure.

The tests used to evaluate development and integration of the body-righting reaction (rolling from supine to prone, transition from supine to standing, and equilibrium in sitting) were presented in counter-balanced order. The methods used in test presentation and scoring followed. The scoring criteria are shown in Table 2.

Rolling from supine to prone was presented with the subject lying symmetrically in supine on a firm gymnastic mat, with head and trunk in alignment, arms and legs extended, slightly abducted, and in midposition of rotation. With the examiner standing at the side of the mat toward which rotation was to occur, the subject was asked to roll slowly toward the examiner. This procedure, repeated twice, resulted in the subject rolling first to the right and then to the left. Right and left rotations were scored separately, with the scoring criteria reflecting the presence or absence of segmental rolling (a score of 0 or 1 point, with a maximum combined score of 2 points). The body segment(s) used to initiate rotation were also recorded for right and left rotations, with the categories used for tabulation based on pre-test videotaped analysis of eight (three learning-disabled and five normal) children. The categories depicting segmental rolling responses included initiation of rotation by either forward flexion of the head, shoulder, head and shoulder, pelvis, or lower extremity. The categories depicting nonsegmental rolling responses included the initiation of rotation by either simultaneous rotation of the head, trunk, and pelvis (log roll); forward flexion of both upper and lower body parts, or extension of the lower extremity paired with use of the medial side of the foot to push against the supporting surface.

Transition from supine to standing was presented with the subject lying symmetrically in supine on the gymnastic mat with head and trunk in alignment, arms and legs extended, slightly abducted and in midposition of rotation. When asking the subject to move to standing, the examiner stood at the end of the mat toward which the subject’s feet were pointed. The amount of trunk rotation observed during the movement pattern was reflected in the scoring (possible score of 0, 1, or 2 points).

Equilibrium in sitting was presented with the subject centrally seated on top of a 31-inch vinyl therapy ball that was partially stabilized in a wooden frame at its base. The subject’s weight was symmetrically balanced (legs partially extended and abducted, feet unsupported) with head and trunk in alignment with a pointer at-
tached to the back of the ball. The pointer, made from a 54-inch collapsible radio antenna, was used to align the vertical axis of the ball with an angle grid taped to the wall 30 inches behind the ball. The angle grid contained a center vertical line and two sets of angled lines (10°, 20°, 30°, 40°, and 50°), one set located to the right and the other to the left of vertical. The examiner knelt in front of the subject with hands bilaterally placed over the center of the subject's thighs, a procedure that provided security for the subject, and maintained the subject's seated position, as well as served as a base from which to elicit postural displacement. Before being placed on the ball, the subject was told that he/she was going to go for a ride. Without further verbal instructions, the subject was seated on the ball and then his/her weight was quickly displaced, first five times to the right and then five times to the left. Before each postural displacement, the subject was returned to vertical and his/her hands placed loosely in his/her lap. Within each direction of displacement, the pointer was randomly aligned with each of the five angles on the angle grid. Right and left responses were scored separately, yielding a score of 0 or 1 point for each direction of postural displacement and a maximum combined score of 2 points.

Table 2
Scoring Criteria for the Tests Measuring Development and Integration of the Body-Righting Reaction

<table>
<thead>
<tr>
<th>Test</th>
<th>Criteria</th>
<th>Scoring Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolling from Supine to Prone</td>
<td>Segmental rotation of the head, trunk, and pelvis was visible; being</td>
<td>1 Point — Segmental rotation of the head, trunk, and pelvis was visible; being initiated by forward flexion of the head and/or shoulder or pelvis and/or lower extremity on the up-hill side of the movement followed by derotation of the remaining body segments.</td>
</tr>
<tr>
<td>Transition from Supine to Standing</td>
<td>SYMMETRICAL PATTERN: Body righting (rotation of the head, trunk, and/or pelvis) was visible.</td>
<td>0 Points — Segmental rotation was not visible. Rotation of the head and body occur simultaneously (log roll), extension of one of more body segments, or flexion of upper and lower body parts assist in rotation.</td>
</tr>
<tr>
<td>Equilibrium in Sitting</td>
<td>Trunk rotation was visible in response to postural displacement to one or more of the 5 measured angles off vertical.</td>
<td>1 Point — Partial rotation was either seen twice in moving first from supine to sitting and then sitting to standing or a combination of partial rotation and symmetrical patterns were seen within the movement pattern.</td>
</tr>
<tr>
<td></td>
<td>Trunk rotation was not visible in response to postural displacement to any of the 5 measured angles off vertical.</td>
<td>0 Points — Full or a combination of full and partial rotation pattern(s) were visible during transition from supine to standing. Movement from supine into prone, quadruped, and/or four-point hands and feet position(s) were sited before reaching kneeling and/or half-kneeling and standing.</td>
</tr>
</tbody>
</table>

Right and left responses were scored separately, yielding a score of 0 or 1 point for each direction of postural displacement and a maximum combined score of 2 points.
trolled by the fact that the examiner was generally unaware of the subjects' group placement. The subjects were escorted to the test area by another occupational therapist, who co-scored the body-righting assessments. Computation of inter-rater reliability resulted in $r = .87$.

**Results**

Comparing the learning-disabled group with the control group indicated that performance on the SVCU score and performance on the combined body-righting assessment score were significantly lower for the learning-disabled group than for the control group. For the SVCU score, use of a one-tailed independent $t$-test resulted in $t = 1.99$ ($p < .05$). The one-tailed Mann-Whitney $U$ Test, used to compare between group performance on the combined body-righting assessment score, resulted in $U = 115.5, Z = -4.43$ ($p < .001$). The mean, standard deviation, and range for the SVCU score and the median and range for the combined body-righting assessment score for the learning-disabled and control groups can be found in Table 3.

The one-tailed Mann-Whitney $U$ Test was again used to determine whether or not there was a significant difference between learning-disabled and control group scores for each of the three tests contributing to the combined body-righting assessment score. The results indicated that the learning-disabled group scored significantly lower than the control group on all three test measures, rolling from supine to prone ($U = 136.0, Z = -2.92, p < .01$), transition from supine to standing ($U = 170.0, Z = -2.44, p < .01$), and equilibrium in sitting ($U = 145.0, Z = -2.92, p < .01$).

Analysis of the body segment(s) used to initiate supine to prone rolling was performed with right/left responses combined (a total of 46 rolling responses for each group). For the control group, 40 rolling responses (87% of the total) resulted in segmental rotation and 6 rolling responses (13% of the total) resulted in nonsegmental rotation of head, trunk, and pelvis. For the learning-disabled group, 26 rolling responses (57% of the total) resulted in segmental rotation and 20 rolling responses (43% of the total) resulted in nonsegmental rotation of head, trunk, and pelvis.

Observation of the body segment(s) used to initiate nonsegmental rotation during supine to prone rolling reflected a similar pattern within the control and learning-disabled (LD) groups. For both groups, approximately half of the total segmental rolling responses were initiated by forward flexion of the shoulder (control group 58%, LD group 54%), with the remaining responses produced by either forward flexion of the pelvis or lower extremity (control group: pelvis = 15% and lower extremity = 22%, LD group: pelvis = 31% and lower extremity = 15%). The remaining 5 percent of the variance for the control group was represented by forward flexion of the head or head and shoulder.

Observation of the body segment(s) used to initiate nonsegmental rotation during supine to prone rolling also reflected a similar pattern within the control and learning-disabled groups. For both groups approximately two-thirds of

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Elementary Statistics for the SVCU and Combined Body-Righting Assessment Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>Learning-Disabled</td>
</tr>
<tr>
<td>SVCU Score</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>23.91</td>
</tr>
<tr>
<td>S.D.</td>
<td>4.85</td>
</tr>
<tr>
<td>Range</td>
<td>13-28</td>
</tr>
<tr>
<td>Combined Body-Righting Assessment Score</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>3.88</td>
</tr>
<tr>
<td>Range</td>
<td>1-6</td>
</tr>
</tbody>
</table>
the total segmental rolling responses were produced by simultaneous rotation of the head, trunk, and pelvis (log roll) (control group 67%, LD group 60%), with the remaining one-third of the nonsegmental rolling responses primarily attributed to use of lower extremity extension paired with the medial extension of the foot used to push against the supporting surface (control group 33%, LD group 35%). The balance of the variance for the learning-disabled group (5%) was credited to simultaneous forward flexion of upper and lower body parts.

Spearman Rank Order correlations were used to determine whether there was a relationship between SVCU and combined body-righting assessment scores within the learning-disabled and control groups. Results found no significant correlation between test scores within either the learning-disabled group (\( \rho = .236, p > .05 \)) or the control group (\( \rho = -.214, p > .05 \)).

**Discussion**

The results upheld the hypothesis that the learning-disabled group would exhibit significantly lower SVCU scores and lower body-righting assessment scores than the normal control group. This supports the findings of past authors, who identified deficits in the development and integration of the body-righting reaction and in the development of manual midline crossing behavior within the learning-disabled population (2, 13, 18, 21).

The results did not support the hypothesis of a relationship between development of the body-righting reaction and manual midline crossing behavior within either the 6- to 8-year-old learning-disabled or normal control group children studied. There are at least two possible explanations for this finding. The first possibility is that a developmental relationship between behaviors either does not exist or exists only during infancy. Thus, the frequent co-existence of deficits in development of the body-righting reaction and manual midline crossing behavior cited by Ayres (2) in the school-aged learning-disabled population might be viewed as a frequently occurring but diagnostically nonmeaningful finding. The second possibility is that a relationship between behaviors exists but, because of methodological limitation(s) of the study, it was not detected. Both test measures used (Space Visualization Test and combined body-righting assessments) hold potential for limiting the research findings. Although validity and reliability studies are still needed, repeated use of the SVCU score within sensory integration testing offers face validity to its usefulness as a method of measuring manual midline crossing behavior. However, the demand for trunk rotation (produced by either need for skilled prehension or the grasping of objects beyond arm’s length) is not required for block manipulation on the Space Visualization Test. It is possible that the relationship between body righting and midline crossing only becomes visible in situations requiring a pairing of trunk rotation and contralateral hand use for task completion. Although the combined body-righting assessments did discriminate between groups, the limited range of possible scores (0 to 6 points) provided for in the test may not have been large enough to produce the degree of between-score variability needed to detect a significant correlation between test scores.

The identification of dysfunction in the development and integration of the body-righting reaction within the learning-disabled group suggests the need for the development of an objective method of measuring body righting for use in sensory integration testing. Such a test measure is not presently included in the battery of standardized tests (Southern California Sensory Integration Tests) and clinical observations commonly used by occupational therapists during evaluation of learning-disabled children. All three tests used in the present study (rolling from supine to prone, transition from supine to standing, and equilibrium in sitting) showed reduced maturation of the body-righting reaction in the learning-disabled group, when compared to the normal control group. However, observation of the children during testing indicated that transition from supine to standing might be the least useful, and rolling from supine to prone the most useful of the three tests in evaluating the performance of individual children.

Analysis of the difference in performance between learning-disabled and normal children during rolling from supine to prone is needed if this movement pattern is to be developed for use as an assessment tool. Observation of the body segment(s) used to initiate supine to prone rolling is viewed as the first step toward such an analysis. The finding of similar body segment use within the learning-disabled and normal control groups during both segmental and nonsegmental rolling responses implies that the reduced frequency of segmental rolling responses seen in the learning-disabled group might reflect a maturational delay in development of the body-righting reaction. Within the segmental rolling responses for the learning-disabled and normal
control groups, rotation was initiated as often through use of upper body (shoulder) as through use of lower body segments (pelvis or lower extremity). It was of interest that within both groups the only methods described as normally occurring within the early maturation of the body-righting reaction (1, 16). Observation of the children during testing reflected variance in right/left responses in some children. This citing, paired with the impression that different body segment use might be seen if rolling was initiated from prone rather than from supine, suggests that these factors should be studied in future analysis of the rolling response.

Although the research findings may aid skilled therapists in refining their subjective assessment of the body-righting reaction in 6- to 8-year-old learning-disabled children, the results are considered preliminary and thus not directly transferable to the clinic setting. The development of a clinically useful body-righting assessment tool is dependent on future research. Such research should include both longitudinal developmental studies and comparative analyses of the differences in performance between learning-disabled and normal children. Because of extreme difficulty encountered when using observational analysis to score the rapidly occurring movement patterns studied, it is strongly recommended that cinematography be used in future investigation of the body-righting reaction.

Additional analysis of the possible relationship between development of the body-righting reaction and manual midline crossing behavior is also needed. Such research should include use of a test other than the Space Visualization Test for measurement of manual midline crossing in order to determine whether a relationship between development of the body-righting reaction and manual midline crossing behavior exists in the school-aged child, when a pairing of trunk rotation and contralateral hand use is required for task completion.

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