Vestibular Stimulation Effect on Language Development in Mentally Retarded Children

(semicircular canals, therapy, PICAC)

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Effects of specific vestibular stimulation and speech therapy on language ability in mentally retarded children were examined. Thirty subjects were assigned to three treatment groups on the basis of the rank order of overall scores on the Porch Index of Communicative Ability in Children (PICAC). Group I received specific vestibular input in addition to specific speech therapy. Group II received specific speech therapy alone. Group III received general speech stimulation. Treatment was given during a 6-week period, Group I receiving semicircular canal stimulation twice a week. Results indicated that all three treatments produce some improvement in general communication skills. Group I showed higher mean percentage gains in all areas of the PICAC, especially verbal, except visual and gestural in which Group II (specific speech) showed highest gains. However, analysis of variance indicated that these differences among groups were not significant.

The hypothetical connection between the vestibular stimulation and language ability or acquisition and implications for future research are discussed.

Vestibular stimulation separately or in combination with other forms of sensory stimulation applied to infants and children has been reported to affect several behaviors, including: an improvement in gross motor ability in normal infants (1), children with Downs Syndrome (2), children with cerebral palsy (3), mentally retarded children (4), and premature infants (5); a decrease in hyperactivity (6); an increase in visual alertness (7); a calming effect and an improvement in the orienting reflex in infants (8-10), and an increase in academic skills of learning-disabled children (11).

Investigations linking stimulation of the vestibular system with language ability or acquisition have been based on hypothetical constructs (12-16). Ayres (13, 14), reporting on learning-disabled children, suggested a linkage between some aspect of language and the vestibular system. Although Ayres could not clarify this specifically, she concluded that "clinical impression and evidence favor an association between the vestibular system and/or sensory integrative therapy and the development of vocalization and fluency of speech..." (13, p 19).

Language improvement using sensorimotor or sensory-integrative therapy has been reported in mentally retarded pre-schoolers (sensorimotor) (17, 18), mentally retarded adolescents (sensorimotor) (19), and mentally retarded adults (sensory integrative) (20). In each of these studies, nonspecific vestibular stimulation was provided (e.g., rolling, rocking). The sensorimotor studies claimed to use modifications of Kephart's and Ayres' therapy programs in their treatment methodologies (17-19). Typically, in the sensorimotor studies, passive applications of sensory input were given, along with activities such as balance beam walking, and angels-in-the-snow. In the study that used sensory-integrative therapy (20), adaptive applications of sensory input were emphasized so that the patient-client usually provided therapeutic sensory input via self-directed, adaptive, functional movements or activities. However, in neither of these approaches were...
attempts made to isolate the effects of a single sensory component, such as the vestibular system, apart from the overall therapy in the treatment regimens used in the cited studies (11, 12).

Based on the above investigations, the present study was designed to explore the value of one component of the sensory-integrative or sensorimotor therapy used in these investigations as supplemental therapy in improving language ability in language-delayed children. Specifically, this study was concerned with the effects of measurable, quantitative vestibular input on the language ability of a population of mentally retarded children. It was hypothesized that the group of children receiving controlled semicircular canal stimulation would show a greater increase in aspects of language ability than two control groups receiving language therapy interventions not involving vestibular stimulation.

Method

Subjects and Materials. Thirty mentally retarded students currently enrolled in a speech therapy program using a block scheduling system were chosen as subjects. All 30 children lived at home and attended special education classes during the day at a central county educational system. Parental permission was received for subject participation. Physician approval was given for vestibular stimulation to assigned subjects. The subjects (15 girls and 17 boys) were between the ages of 5 and 14 years (Mean = 9.2 years) with IQs between 28 and 69 (Mean = 44.8). Subject IQ was determined by school staff psychologists using standard psychometric tests (WISC, SB) (Table I).

Communicative skills were evaluated using the Porch Index of Communicative Ability in Children (PICAC) (21). The PICAC is a standardized, highly reliable clinical test to evaluate and quantify communicative abilities in a child or populations of children. The PICAC, because of its multidimensional scoring system, can sensitively document effects of treatment on maturation in language abilities over periods of time as short as 4 weeks. It has been used with various populations of children including learning-disabled, autistic, and mentally retarded (Porch, personal communication, January 1979). In the basic PICAC, 16 subtests assess visual, auditory, graphic, gestural, and verbal language skills. By combining the scores of each of the 16 subtests in assigned ways, each language skill area is given a score of 1 to 16. In addition, an overall score, which includes all 16 subtests, and a general communication score, which includes all subtests except graphic and reading, can be tabulated.

Pre- and post-testing were administered by four speech pathologists trained and certified in giving the PICAC. The testers were independent of, and unaware of, treatment methodologies and subsequent groupings of the test subjects. The 30 children were assigned to 3 treatment groups based on the ranked order of their individual overall scores on the PICAC so that each group had equal representation of high and low scores. After 6 weeks of treatment each subject was post-tested within 24 to 48 hours of the last treatment session.

Treatment Procedure. Group I—Vestibular/Specific Speech Therapy. Vestibular treatment consisted of stimulation of specific pairs of semicircular canals on 2 days a week during the 6-week period. A hand-operated rotary chair fitted with velocity indicators was used to provide the necessary angular acceleration stimulus to the semicircular canals. The horizontal semicircular canals were positioned in the horizontal plane by tilting the child's head forward approximately 30 degrees from the vertical with the aid of an adjustable head rest. The paired vertical (anterior and posterior) canals were positioned in the horizontal plane by positioning the child's head approximately 90 degrees from the vertical in the frontal plane with the chin pointed down about 45 degrees. Each vestibular stimulus consisted of a 2- to 5-second acceleration, a 1-minute period of constant angular velocity at 150 degrees per second (25 RPM), and an impulsive stop. An interval of 30 to 45 seconds between each stimulus was allowed. During each treatment session, each subject received up to two stimuli to the horizontal canals (clockwise and counterclockwise) and eight stimuli to the vertical canals (four clockwise and four counterclockwise) depending on the child's tolerance. Each vestibular treatment was given by the senior author.

Specific speech therapy consisted of individualized language programs as deemed necessary by each child's assigned speech pathologist. The speech pathologist giving treatment was unaware of the PICAC results. The Language Acquisition Program (LAP) (22) was the primary source of assigned programs. During the 6-week time block, the individual child progressed through the LAP sequential training format at his or her own rate. The specific speech therapy sessions were given four times per week during the 6-week period. Each speech therapy session lasted 10 to 12 minutes. As part of the child's
Table 1
Treatment groups with sex distribution, mean age, and IQ for each group after rank order assignment of sample population

<table>
<thead>
<tr>
<th>N</th>
<th>Group</th>
<th>Mean Age (Yr)</th>
<th>IQ</th>
<th>Sex</th>
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<tbody>
<tr>
<td>10</td>
<td>I (Vestibular/Specific Speech Therapy)</td>
<td>9.3</td>
<td>420</td>
<td>5</td>
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<tr>
<td>10</td>
<td>II (Specific Speech Therapy Only)</td>
<td>7.7</td>
<td>459</td>
<td>6</td>
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<tr>
<td>10</td>
<td>III (General Speech Therapy Only)</td>
<td>10.6</td>
<td>464</td>
<td>7</td>
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Table 2
Pre- and post-test mean and standard deviation values for each treatment group on the PICAC overall, general communication, verbal, gestural, visual, and auditory and graphic language areas

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<td>Group I</td>
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<tr>
<td>pre-test</td>
<td>7.95 ± 2.18</td>
<td>9.28 ± 2.99</td>
<td>8.39 ± 3.00</td>
<td>10.56 ± 2.57</td>
<td>10.47 ± 2.79</td>
<td>11.70 ± 4.02</td>
<td>5.58 ± 2.17</td>
</tr>
<tr>
<td>post-test</td>
<td>8.67 ± 2.05</td>
<td>10.07 ± 2.80</td>
<td>7.60 ± 3.70</td>
<td>10.81 ± 2.13</td>
<td>10.82 ± 2.45</td>
<td>12.19 ± 3.45</td>
<td>5.95 ± 2.26</td>
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<td>Group II</td>
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<tr>
<td>pre-test</td>
<td>8.37 ± 2.04</td>
<td>9.84 ± 1.93</td>
<td>7.19 ± 2.34</td>
<td>10.66 ± 2.31</td>
<td>10.74 ± 1.90</td>
<td>11.77 ± 1.66</td>
<td>5.41 ± 2.84</td>
</tr>
<tr>
<td>post-test</td>
<td>8.92 ± 2.11</td>
<td>10.44 ± 2.02</td>
<td>7.82 ± 2.94</td>
<td>11.52 ± 1.66</td>
<td>11.45 ± 1.68</td>
<td>12.18 ± 1.77</td>
<td>5.59 ± 2.26</td>
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<tr>
<td>Group III</td>
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<tr>
<td>pre-test</td>
<td>9.88 ± 2.18</td>
<td>11.64 ± 2.07</td>
<td>9.87 ± 2.68</td>
<td>11.54 ± 1.00</td>
<td>11.88 ± 1.65</td>
<td>12.66 ± 2.13</td>
<td>6.19 ± 3.10</td>
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<tr>
<td>post-test</td>
<td>10.04 ± 2.07</td>
<td>11.97 ± 1.99</td>
<td>10.44 ± 2.78</td>
<td>11.79 ± 0.60</td>
<td>12.04 ± 1.56</td>
<td>12.70 ± 2.08</td>
<td>6.14 ± 3.20</td>
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</table>

*Does not include graphic subtest H.

Table 3
Correlation between overall and language skill areas and IQ and age for 30 subjects on differences between pre- and post-test scores

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<tr>
<td>Age</td>
<td>.20 NS</td>
<td>-.08 NS</td>
<td>.31 NS</td>
<td>-.12 NS</td>
<td>-.54 (.008)</td>
<td>.04 NS</td>
<td>-.24 NS</td>
<td>-.04 NS</td>
<td>-.01 NS</td>
<td>.005 NS</td>
<td>.09 NS</td>
</tr>
<tr>
<td>IQ</td>
<td>-.04 NS</td>
<td>-.01 NS</td>
<td>.005 NS</td>
<td>-.35 NS</td>
<td>-.30 NS</td>
<td>.12 NS</td>
<td>-.30 NS</td>
<td>-.30 NS</td>
<td>-.30 NS</td>
<td>-.30 NS</td>
<td>.12 NS</td>
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</table>

NS = not significant.
Level of significance in parentheses.

language program each subject's classroom teacher was given specific language activities to carry over in the classroom.

**Group II—Specific Speech Therapy/Control Handled:**

Specific speech therapy was designed for each subject in Group II, as described previously for Treatment Group I. In order to control for interaction with the senior author and the novelty of the vestibular treatment equipment, Group II subjects were also seated in the vestibular chair two times per week during the 6-week period for approximately 2 minutes. Group II subjects, however, were not spun.

**Group III—General Speech Therapy/Control:**

Group III subjects would normally have been in the off therapy time on the block scheduling system. Group III subjects received general speech and language stimulation four times per week for 6 weeks from the speech therapist. In this situation, the therapist read books and played records that were consistent with the subject's maturation and classroom level. Sessions lasted 10 to 12 minutes.

**Results**

Interrater reliability was calculated by using the scores from each of the four testers after scoring a randomly selected videotape playback of one subject's scoring session. This provided a comparison of 100 points for each tester. The Pearson product moment correlation coefficient of each tester to the other was highly significant, and ranged from $r = 0.07$ to $r = 0.99$.

Mean pre- and post-test scores from the PICAC test are shown in Table 2. Figure 1 describes mean percent improvement from pre-test to post-test for overall language skill areas for the three treatments. Group I showed greater gains than Groups II or III in all areas except visual and gestural, with greatest mean improvement (19%) seen in the Group I verbal language area.

Results of ANCOVA when age, IQ, and pre-test scores were controlled revealed no significant difference in post-test scores between groups.

Correlational analysis indicated that differences from pre-test to post-test scores for the 30 subjects could not be attributed to the pre-disposing factors of age or IQ (Table 3).

The children in Group I showed a range of tolerance for vestibular
Table 4
Number of spins tolerated by group I subjects for each day of treatment

<table>
<thead>
<tr>
<th>Day of Treatment</th>
<th>1</th>
<th>2</th>
<th>3</th>
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* Discontinued—post-test done within 24 to 48 hours
H = Horizontal semicircular canal
V = Vertical semicircular canal

stimulation. Most subjects increased their tolerance to the treatment over the 6-week period, but two became less tolerant and were discontinued from treatment at the end of the fifth week (Table 4). Data from their post-test were included in the analysis. There was no significant correlation between the tolerance of a child to the vestibular treatment and his or her improvement on the PICAC test.

Discussion
The data analysis does not support the hypothesis that specific vestibular stimulation produces a significantly greater increase in overall language ability than language intervention therapy alone as measured by the PICAC. However, the trends of greater gains by subjects in the specific vestibular stimulation group merit further comment and discussion (Figure 1).

Group I, which received vestibular stimulation and specific speech therapy, showed a 9.06 percent mean improvement overall. Group II, which received only specific speech therapy, showed a 6.57 percent mean improvement, and Group III, which received general speech and language stimulation, showed only a 1.62 percent mean improvement overall.

The scores in the language skill areas reflected the overall scores. The greatest mean improvement (19%) was seen in the Group I verbal language area (Figure 1). The vestibular stimulation group (Group I) showed greater improvement than Groups II or III in all language skill areas except visual and gestural, as measured by the PICAC. Individual variation in improvement was considerable with one subject showing a 200 percent increase in the auditory language area in Group I.

Our investigation attempted to isolate the effects of vestibular input from the effects of speech therapy. Vestibular stimulation was applied based on knowledge of the anatomy and neurophysiology of the vestibular system. To investigate vestibular stimulation alone, it was necessary to apply vestibular stimulation in a very specific and passive manner. Sensory-integrative therapy includes...
vestibular stimulation as part of its program, but incorporates it within multisensory experiences, that is, adaptive or functional movements. In programs that reported gains in language skills, several forms of therapy were used, most of which incorporated some kind of vestibular stimulation (17–19, 13, 20). Support for the theory that vestibular stimulation is one of the most potent, single elements of those therapy programs in which language gains were reported remains inconclusive; however, interesting trends of influence are noted in this study.

The mechanism for the verbal, expressive language-vestibular stimulation relationship remains elusive. Perhaps the same CNS integrator responsible for gross motor improvement from vestibular stimulation also modifies fine motor mechanisms of speech either at an intersensory modulation level and/or muscle spindle level (4, 1, 2).

A more elaborate explanation is possible. The ability of the normal child to comprehend and use language is a complex process that escapes final definition or complete understanding. The mentally retarded child apparently: a. acquires language later or slower than normal, b. has a higher incidence of disorders than those of the general population, and c. these disorders do not differ in kind from those of nonretarded children (23). One can think of language, including verbal expressive language, as being the result of the CNS establishing sensory priority (24). In the normal child, “priority” is given to all sensory input relevant to language coding and recoding so that adaptive language responses can be made.

Electrophysiological patterns made, differentiated, and elaborated by the balance of inhibitory and facilitory mechanisms functioning in the brain stem reticular system help set sensory priority. These patterns act at alert or arouse the rest of the CNS so that more efficient synaptic transmission can be made (25, 26). The reticular system can be thought of as sensitizing specific cortical areas to the reception of certain temporal-spatial wave patterns and preventing noncritical neuronal assemblies from exhibiting responses of attention (24). If the reticular system is not setting neuronal patterns in an organized, selective manner, then higher cortical patterns will be distorted or will be temporally and spatially out of synchrony. This will result in a distorted verbal perception and expression.

Slow language acquisition by the mentally retarded child may be the result of improper or inadequate facilitation-inhibition at reticular synaptic levels. This failure could produce a distortion of attention to language stimuli at subsequent higher subcortical and cortical levels. The vestibular system has been reported to modulate other sensory input signals (27, 28), and to influence the orienting reflex (11), arousal level (29), and attention (8, 30, 7) in humans. The vestibular stimulation used in this study possibly modified arousal or attention levels in the treatment subjects of Group I. As a consequence, proper temporal-spatial patterns were set in the reticular system and more adaptive responses could be made in language skills, especially verbal expressive language skills as measured by the PICAC.

The therapist using passive vestibular stimulation should be aware of the special precautions regarding autonomic effects including nausea, dizziness (31), and possible contraindications when working with seizure-prone children (12, 14). Also, it would be valuable to be able to predict the relative effectiveness of vestibular stimulation therapy from the response (i.e., autonomic, behavioral) of the child to his or her first encounter with vestibular stimulation. Adult populations, including astronauts examined for tolerance to vestibular stimulation, showed a wide range of individual tolerance. Continued exposure to vestibular stimulation is reported to produce increased tolerance (32). Two subjects in this study decreased their tolerance. These two subjects responded with vegetative signs (e.g., sweating) and became more emotionally distressed as the treatment session continued, indicating that their reaction was substantive and not a result of boredom. Among the ten subjects of Group I who received vestibular stimulation therapy, the response to the stimulation as measured by number of spins tolerated did not correlate with their improvement on the PICAC test. Although the children who were ranked ninth and tenth in tolerance were ranked first and second, respectively, in points gained on the PICAC, the subjects ranked seventh and eighth in tolerance were ranked ninth and tenth, respectively, in points gained at the end of treatment. Therefore, initial reaction to vestibular stimulation treatment, at least in this study, was not predictive of language improvement.

Summary
The results of this study failed to confirm or deny a definite vestibular stimulation-language acquisition link. However, the trends reported suggest the supportive role of vestibular input in programs such as sensory-integrative therapy that use vestibular stimulation in a multisensory, active, adaptive approach with various populations of devel-
opmentally delayed children, including mentally retarded. Vestibular stimulation in combination with other kinds of sensory stimulation may prove to be more potent than the specific stimulation used in this study.

Future clinical studies are needed with larger and more controlled populations of mentally retarded and normal children before effects of vestibular stimulation on language can be more clearly defined. For these studies it may be advisable to compare three treatments among homogeneous groups: sensory-integrative therapy alone, specific vestibular stimulation therapy alone, and specific speech therapy alone to language-delayed children. The PICAC or other highly specific language evaluation tools could be used to monitor treatment effects with appropriate statistical analysis.

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REFERENCES