

# Evaluation of Vestibular Proprioceptive (VPP) functioning in children: identification of relevant test items

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## ABSTRACT

*This study was undertaken in the absence of a standardised test to evaluate vestibular proprioceptive processing (VPP). By a process of test development, 18 appropriately difficult and clearly discriminatory test items were identified. These test items can now be used as a basis to assemble and standardise a VPP test.*

**Key words:** Vestibular proprioceptive processing, sensory integration, test development, evaluation.

## Introduction

Vestibular proprioceptive processing (VPP) has been described by sensory integration theorists<sup>1,2</sup> as the processing of input received from the proprioceptors in both the vestibular apparatus and in muscles and joints. As it is not, at this stage, possible to differentiate between the extent of the contribution of the vestibular system or the muscles and joints for postural control or motor performance, both are included as the VPP system. Thus there is a range of clinical manifestations of VPP functional deficits. According to the literature, children with VPP problems present with poor equilibrium reactions, poor ocular responses, low muscle tone, unintegrated primitive tonic reflexes, poor posture, poor awareness of proprioception and gravitational insecurity and intolerance of, or aversive response to movement. All of these can be associated with learning disabilities as well as motor co-ordination deficits<sup>2</sup>.

The research reported in this article was stimulated by the absence of a standardised test which could discriminate clearly between children with and without VPP problems. Although individual test items to evaluate VPP are available in the literature, most are not standardised. Those that are standardised form part of various other test batteries which do not test VPP as such.

As a proper diagnosis or evaluation of these problems is necessary to make specific, practical decisions for any treatment, and no standardised test battery exists, this research was undertaken.

The purpose of this study was therefore to establish a standardised test which could discriminate clearly between children with and without VPP problems. The research focused on the first steps towards standardisation, viz. the identification of suitably difficult, clearly discriminatory test items. Furthermore, the South African Institute for Sensory Integration requested that such a test be developed.

## Materials and methods

The study was conducted through three phases viz. a pilot study and two phases. Three different sets of materials were used during this process. The results of the pilot study determined the materials for phase 1 and the results of phase 1 determined the materials to be used for phase 2.

Table 1 shows the process used to develop the initial 45 test items into 18 usable test items, as well as the samples of children used in each phase.

## Study sample

This study should be regarded as only the starting point in the construction of a standardised VPP test with the main purpose being the identification of suitable test items<sup>3,4</sup>. Therefore, a convenience sampling method<sup>5</sup> was used. Children, who were available and who met the criteria for the pilot study and the two phases, were included in the sample and selected from two Pretoria primary schools, two special education schools and from private Occupational Therapy practices.

The common criteria for inclusion of the population from which the samples for the different phases were selected was an age range of 6 years to 7 years 11 months, a normal IQ and no motor neuron damage or epilepsy. Specific additional criteria were set for the sample

in the different phases viz. children without known VPP dysfunction were selected from mainstream primary schools for the pilot study and for phase 1. In phase 2, children with suspected VPP dysfunction were selected based on clinical observations undertaken by qualified occupational therapists.

## Ethical considerations

Informed consent was obtained from the principals of the two schools, the occupational therapists and the parents of the children included in the sample.

Ethical clearance was obtained from the Research and Ethics Committee of MEDUNSA (ethics clearance certificate number: MP32/97).

## Development of test items

As VPP is an internal process and is only revealed by the behaviours related to it, test items were collected from literature and from existing tests by using these behaviours as a guide. The following behaviours relating to VPP<sup>2,7,8,9,10</sup> were found in the literature:

- 1) balance (including righting and equilibrium reactions),
- 2) muscle tone,
- 3) posture,
- 4) proprioception,
- 5) gravitational insecurity and intolerance of, or aversive response to, movement,
- 6) ocular responses and
- 7) primitive tonic reflexes.

| Phase       | N test items | Steps used in each phase                                                                                                                                                                                                                                                                                                                                                   | Resulting N test items |
|-------------|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|
| Pilot Phase | 45           | Behaviour, by which VPP is manifested, was defined, using literature.<br>A test plan was written.<br>Test items were collected from the literature <sup>3,4,5,6</sup> or were developed meeting criteria on manifested behaviour of VPP.<br>A preparatory study was undertaken to help refine ideas, test items and procedures by trying the test items out on 5 children. | 31                     |
| Phase 1     | 31           | Test items were tried-out on 97 children (without dysfunction).<br>Items were analysed for item difficulty value.<br>The developmental edition of the test was assembled.                                                                                                                                                                                                  | 26                     |
| Phase 2     | 26           | The developmental edition was tried-out on 83 children who were a representative sample of VPP dysfunction.<br>The developmental edition was analysed for difficulty value and discrimination power.                                                                                                                                                                       | 18                     |

Table 1: Phases of the study

The study was limited to the first four behaviours plus the addition of labyrinthine function. This function was added to accommodate all the test items which required closed eyes as well as the tonic labyrinthine reflex. A total of five behaviours were thus used in the study.

Furthermore, criteria for the collection of test items were established. Firstly, they had to evaluate VPP; secondly, they had to be cost effective and affordable in the South African context, and thirdly, the range of test items (in relation to the behaviours) had to be as varied as possible.

The literature search resulted in 59 test items which corresponded to the behaviours mentioned above; and of these 45 were selected by using the following criteria:

- The test items had to consist of novelty tasks not known to the children to exclude the evaluation of overly practised skills.
- The cost of equipment had to be kept low as requested by the South African Institute for Sensory Integration, for whom the test was being developed, so that the test would be affordable for all OT practitioners.
- The child should perceive no ambiguities while being tested, as any misinterpretations would influence the reliability of the test.

Table II lists the number of test items used for the different phases of the study as well as the number of test items refined, discarded, added or remaining unchanged. Test items were refined by altering equipment, instructions, time limits and methods of administration and scoring, to meet the set criteria. Furthermore, the researcher modified nine of the test items to be cost effective and to facilitate scoring.

|                             | Refined test items | Discarded test items | Unchanged test items | Additional test items |
|-----------------------------|--------------------|----------------------|----------------------|-----------------------|
| Pilot study - 45 test items | 18                 | 20                   | 7                    | 6                     |
| Phase 1 - 31 test items     | 6                  | 5                    | 20                   | 0                     |
| Phase 2 - 26 test items     | 0                  | 8                    | 10                   | 0                     |
| Result 18 test items        |                    |                      |                      |                       |

Table II: Development of test items throughout the study

## Scoring of test items

Two types of scoring methods were used namely a key scoring method and a measurement unit scoring method. In the *key scoring method*, a list of responses (named keys) specific to each test item was given. The list was divided into three groups of scores namely a "0", "1" and "2".

A zero (0) (no deficit) indicated that the child executed the test item effectively; a "1" (some deficit) indicated responses of less effective execution, whereas a "2" (definite deficit) indicated a failure to execute that test item. Both the literature and the experience of the researcher were used to determine these scores.

A *measurement unit scoring method* was used where the literature was not clear on the scale for scoring and if there was no previous method or key to determine how scores should be allotted. These test items were scored by measurement units of time or by deviation from the starting point and also by the number of steps or errors in executing the test item. Both a key score and a measurement unit score, as described in the literature, were used to measure some of the test items.

Seven different postural positions, in which behaviours of VPP could be evaluated, were used to prepare a score sheet. These different positions were mentioned in the literature<sup>2,9</sup>, and these were supine, prone, standing, one leg standing, walking, sitting and kneeling. The researcher grouped the test items for the different positions together as this would make test administration

easier and be less time consuming. An extract of the score sheet is shown in Table III.

Test items marked \* were scored by the key scoring method.

| Name                                                                                            | D.O.B. |                            |   | Date:        |    |                                                                                                                      |
|-------------------------------------------------------------------------------------------------|--------|----------------------------|---|--------------|----|----------------------------------------------------------------------------------------------------------------------|
| Test item                                                                                       | P      | L                          | T | B            | Pr | Comments                                                                                                             |
| 16. Walking forwards on walking line                                                            |        |                            |   | Steps<br>Sec |    | Off line, hand off hips, loses balance.                                                                              |
| 18. Walk on floor heel-to-toe eyes closed                                                       |        | Errors<br>Sec              |   |              |    | Not touching, moves back foot, steps on toes, hand off hips, eyes open.                                              |
| 21. Stepping test                                                                               |        | A B<br>C D<br>1 2 3<br>4 5 |   |              |    | High guard, medial feet, lateral feet, knees hyperextends, braces, rigid, clumsy, falls, deviation to left or right. |
| 25. Protective extension                                                                        |        | *                          |   |              |    | No extension in arms or legs, slow extension in arms or legs, difference in response, falls on elbows, falls.        |
| 26. Sitting Posture                                                                             | *      |                            |   |              |    | Posterior pelvic tilt, hyper extension of neck, feet around chair legs.                                              |
| Key P = posture      L = labyrinth      T = muscle tone<br>B = balance      Pr = proprioception |        |                            |   |              |    |                                                                                                                      |

Table III: Extract of the score sheet

## Results

Due to the process followed in developing the test i.e. the results of one phase influenced the materials and methods to be used at the next phase, each stage will be reported in terms of the methods used, the results obtained and the number and type of child evaluated.

### The Pilot study

The first step was a pilot study in which 5 children without VPP dysfunction were evaluated to try out the test items and procedures. At this stage 14 test items were discarded, as they were very difficult and almost impossible to execute for children in the chosen age group. Other test items left possibilities for inconsistency in scoring, were too difficult to administer and score at the same time or equipment was also used in therapy which would be too familiar to some of the children. Thus 31 test items were brought forward into phase I of the study.

### Phase I

In phase I, a group of 97 children (who were previously evaluated to be without dysfunction) were evaluated with the test items, which resulted from the pilot study.

Firstly, the difficulty value for each of the *key scored test items* was calculated by determining the percentage of "0" scores per test item. Test items with a high percentage of "0" scores were easy and those with a low percentage of "0" scores were difficult. Considering that normal children were tested in phase I, and that a "0" score indicated perfect execution of a test item, it was expected that the percentages "0" scores for each test item would be high, indicating a high percentage of children without dysfunction who were able to execute a specific test item perfectly. Difficulty values of the *key scored test items* of phase I are shown in Table IV.

Those items marked by an asterisk \* in Table IV, had an acceptable difficulty value, because between 57 to 95 children (i.e. between 58,8% to 97,9%) had a score of "0". The group of items for which the children's scores were too easy (> 97,9%) or too difficult (< 58,8%) were excluded. This left 13 items in the test.

Secondly it was, found that it was not possible to obtain a difficulty value for the *measurement unit scored test items*, as there was



| Test item | Number of children | “0” Scores |    |
|-----------|--------------------|------------|----|
|           |                    | %          | N  |
| 1         | 97                 | 99%        | 96 |
| 2 *       | 97                 | 90,7%      | 88 |
| 3         | 97                 | 100%       | 97 |
| 4         | 97                 | 100%       | 97 |
| 5 *       | 97                 | 80,4%      | 78 |
| 6 *       | 96                 | 84,4%      | 81 |
| 7 *       | 97                 | 97,9%      | 95 |
| 8 *       | 97                 | 96,9%      | 94 |
| 9 *       | 97                 | 79,4%      | 77 |
| 10        | 97                 | 100%       | 97 |
| 24 *      | 97                 | 92%        | 89 |
| 25 *      | 97                 | 97%        | 94 |
| 26 *      | 97                 | 85%        | 82 |
| 27 *      | 97                 | 58,8%      | 57 |
| 28 *      | 97                 | 86%        | 83 |
| 29 *      | 97                 | 94%        | 91 |
| 30 *      | 97                 | 88%        | 85 |
| 31        | 97                 | 58%        | 56 |

\*Acceptable difficulty value

Table IV: Difficulty values of key scored test items of Phase I

no indication of a norm from which the difficulty value for these items could be determined. Therefore, all of the *measurement unit* scored test items together with the 13 key scored items formed the *developmental edition* of the VPP test after refinement of some of the items to facilitate administration and scoring.

## Phase 2

In the various steps of phase 2 the results from evaluating the 97 children without deficits as well as results from testing 83 children with possible VPP deficits were used in the analysis of the test items.

As key scores were needed to statistically analyse the test items, the first step in this phase was to convert the *measurement unit* scores to *key scores*. To do this the mean scores for each *measurement unit* scored test item for phase 1 and for phase 2 were calculated. For each test item the significant difference of the mean scores of the two phases was determined by using a t-test for independent samples. When the p value for an item was  $p \leq 0,05$ , it was converted to a *key score*, as this indicated that a significant difference between the results of phase 1 and phase 2 existed. Three items out of the twelve *measurement* scored items were rejected at this stage and 9 items were converted to the key scoring method using the same method as was used by Miller<sup>11</sup> as follows: The best scores of the non-dysfunctional group added up to 75%. The best scores for test items in phase 1, closest to the mean scores were calculated as close to 75% as was possible and these were allocated the best key score (“0”). To determine the “1” and “2” (deficit) scores, the weakest scores closest to the mean scores of phase 2 were used, as children with possible VPP deficits were evaluated in this phase.

Each test item was then screened for possible inclusion in a VPP test, depending on whether or not a statistically significant difference was found in the scores obtained for phases 1 and 2. This was done by:

- applying the Fisher exact tests to the numbers of “0” scores of the key scored test items in the two phases,
- applying t-tests to the mean scores of the test items scored by measurement units in the two phases.

A statistically significant difference between phases 1 and 2 was indicated by  $p \leq 0,05$ . As phase 1 children were assumed to be without dysfunction, and phase 2 children were assumed to have a dysfunction, a significant difference would indicate that a test item could be considered for inclusion in a VPP test.

## Difficulty value of items in the developmental edition

The difficulty value of a test item is the proportion of children

who performed the test item as would be expected. Scores of both phases of the study were used to calculate this value, as the children, chosen for either phase, were at the end of the spectrum of non-dysfunctional versus dysfunctional. The proportion of zero scores obtained for a test item for both the non-dysfunctional and dysfunctional groups in the total sample was defined as the difficulty value. The easier the test item, the higher was the difficulty value. As can be seen in Table V, the test items were grouped into those with appropriate difficulty values and those with too high or too low difficulty values. The latter two were discarded in the final version of the test.

| Test item (N=24)        |     | Difficulty values (N=26) |
|-------------------------|-----|--------------------------|
| 2                       | *   | 0,538                    |
| 3                       | ⊗   | 0,850                    |
| 5                       | *   | 0,527                    |
| 6                       | *   | 0,614                    |
| 7                       | ⊗   | 0,777                    |
| 8                       | *   | 0,644                    |
| 9                       | *   | 0,622                    |
| 10                      | ⊗   | 0,961                    |
| 10 left and right hands | ⊗ * | 0,688                    |
| 10 left and right hands | ⊗ ⊗ | 0,705                    |
| 11                      | *   | 0,538                    |
| 12                      | *   | 0,533                    |
| 13                      | *   | 0,538                    |
| 14                      | *   | 0,461                    |
| 15                      | *   | 0,500                    |
| 17                      | *   | 0,550                    |
| 18                      | *   | 0,494                    |
| 20                      | *   | 0,502                    |
| 21                      | *   | 0,620                    |
| 25                      | ⊗   | 0,792                    |
| 26                      | *   | 0,623                    |
| 27                      | L   | 0,382                    |
| 28                      | *   | 0,584                    |
| 29                      | ⊗   | 0,735                    |
| 30                      | *   | 0,629                    |
| 31                      | *   | 0,401                    |

\* Appropriate difficulty values  
 ⊗ Too high difficulty values  
 L Too low difficulty value

Table V: Difficulty values of test items in the developmental edition

## Discrimination power

The discrimination power of each test item in the developmental edition was also calculated.

The discrimination power of a test item is its ability to distinguish whether a subject has or does not have dysfunction. It is measured by *sensitivity* and *specificity* of the item, where:

- Sensitivity is the proportion (converted to a percentage) of children in the normal group without deficit as measured by the test item.
- Specificity is the proportion (converted to percentage) of children in the deficit group diagnosed as having a deficit by the test item.

To select the test items with the best discrimination power, the sensitivity as well as the specificity had to be high. Table VI shows that the test items were divided into three groups (high, average and low) depending on the sensitivity and specificity of test items. This resulted in groups of weak, average and high discrimination power.

## Selection of suitable test items for the VPP test

Finally in phase 2 the 18 test items comprising the final version of the VPP test were selected. There were three groups of suitable test items namely excellent, very good and fair which were selected

|                                                                                              |                | Sensitivity |                |                                       |
|----------------------------------------------------------------------------------------------|----------------|-------------|----------------|---------------------------------------|
|                                                                                              |                | Low<br>N=0  | Average<br>N=2 | High<br>N=22                          |
| Specificity                                                                                  | High<br>N=13   |             | 27,31<br>⊗     | 2,5,8,11,12,13,14,15,17,18,20,28<br>* |
|                                                                                              | Average<br>N=7 |             |                | 6,9,21,26,29,30<br>⊗                  |
|                                                                                              | Low<br>N=4     |             |                | 3,7,10,10(↑),10(↓), 25<br>L           |
| L Weak discrimination power<br>⊗ Average discrimination power<br>* High discrimination power |                |             |                |                                       |

Table VI: Discrimination power determined by sensitivity and specificity for test items of both phases

by taking both the difficulty value and the discrimination power into consideration as is shown in Table VII.

|                  |                                                                            | Discrimination Power                                                       |                                                           |
|------------------|----------------------------------------------------------------------------|----------------------------------------------------------------------------|-----------------------------------------------------------|
|                  |                                                                            | High discrimination<br>power<br>N = 12                                     | Average discrimination<br>power<br>N = 6                  |
| Difficulty value | Best difficulty values<br>(0,5 rounded to the first decimal)               | <b>The excellent group</b><br>Test items: 2, 5, 11, 12, 13, 15, 17, 20, 28 |                                                           |
|                  | Appropriate difficulty values<br>(0,4 or 0,6 rounded to the first decimal) | <b>The very good group</b><br>Test items: 8, 14, 18                        | <b>The fair group</b><br>Test items: 6, 9, 21, 26, 30, 31 |

Table VII : Groups of suitable test items

Table VIII lists the various test items in the final version which were selected for each of the behaviours based on the difficulty levels as well as the discrimination levels.

|                           | Excellent N=9                                                                                                                                                                                                    | Very good N=3                                                                                       | Fair N=6                                                       |
|---------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|----------------------------------------------------------------|
| <b>Posture</b>            |                                                                                                                                                                                                                  | Standing posture (Test item 8)                                                                      | Sitting Posture (Test item 26)                                 |
| <b>Labyrinth function</b> | Tonic Labyrinthine Reflex Supine (Test item 2)<br>Tonic Labyrinthine Reflex Prone (Test item 5)<br>Sharpened Romberg eyes closed (Test item 12)<br>Standing one leg on balance beam - eyes closed (Test item 15) | Standing one leg eyes closed (Test item 14)<br>Walk on floor heel-to-toe eyes closed (Test item 18) | Stepping Test (Test item 21)                                   |
| <b>Muscle tone</b>        | Placing and tapping (Test item 28)                                                                                                                                                                               |                                                                                                     | Prone on elbows (Test item 6)<br>Co-contraction (Test item 31) |
| <b>Balance</b>            | Sharpened Romberg eyes open (Test item 11)<br>Standing one leg on floor (Test item 13)<br>Walking forwards heel-to-toe on walking line (Test item 17)<br>Walking heel-to-toe on balance beam (Test item 20)      |                                                                                                     | Standing side to wall (Test item 9)                            |
| <b>Proprioception</b>     |                                                                                                                                                                                                                  |                                                                                                     | Finger to nose (Test item 30)                                  |

Table VIII: Useable test items; representation of behaviours and grouping of suitability

## Discussion and conclusion

This study was undertaken because the need for a comprehensive standardised test to identify solely VPP dysfunction in children, was

expressed by South African occupational therapists; and a full literature search confirmed the absence of such a test, both locally and internationally. This study resulted in the identification of eighteen such test items, which can be used as a basis for a VPP test.

Further investigation of some of the test items as well as of some of the behaviours is, however, still necessary. As this study was limited to five of the seven behaviours described in the literature, it is necessary to investigate the remaining behaviours to develop a complete test.

In conclusion, it is suggested that the efficiency in evaluating VPP will be improved by using a test with the sole purpose of evaluating VPP. This study was an attempt in that direction. The 18 test items which were shown to be clearly discriminatory and suitably difficult as identified by this study, can now be used as a basis to continue the development of an accurate assessment of VPP in children. The final steps required are:

- to establish age bands,
- to assemble and standardise test items and
- to undertake technical analysis of test items, including reliability and validity studies.

## Acknowledgements

I wish to acknowledge the assistance given to me by Estelle Shipham during the research process and in the preparation of this article and also to Elna Jooste for assistance during the research process.

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