Convergent validity of the Richmond Reversal Rating in relation to visual-spatial perception as measured by the SASP

Lucinda Venter, BSc OT (Hons) (ECU)

Janet Richmond, BOT (Hons) (UP), MOT (UKZN), PhD (ECU)
Senior Lecturer, School of Medical and Health Sciences, Edith Cowan University, Australia

Myra F Taylor, MPhil, PhD
Research Fellow, Edith Cowan University, Australia

ABSTRACT

This study examined the convergent validity of the visual perceptual Richmond Reversal Rating (RRR) assessment, in relation to visual-spatial abilities of young school-aged children, using known-groups validity and convergent validity hypotheses testing. Seventy-two primary school children (Years 1-3) were assessed with the RRR assessment and the Spatial Awareness Skills Program Test (SASP). The Kruskal-Wallis test demonstrated a significant difference between the RRR overall scores and the SASP grouped scores, $H(2) = 6.155$, $p = .046$. Spearman’s correlation coefficient revealed a low positive yet significant correlation ($r_s = .433$, $p = .000$) between the RRR overall scores and the SASP percentile scores, and a significant moderate positive correlation between the RRR overall scores and the SASP scores ($r_i = .666$, $p = .000$). The results provide evidential support for the convergent validity of the RRR assessment in relation to visual-spatial abilities as measured by the SASP.

Key words: Letter reversals, number reversals, visual-spatial abilities, school based occupational therapy

INTRODUCTION

Since the twentieth century, children’s visual motor and visual-spatial perceptual reading and writing errors have been a phenomenon of ongoing interest.1-10 Children who have difficulty identifying the accurate orientation of numbers and letters often perform at a lower academic level, have lower reading abilities, and have less legible handwriting than their peers.11-15 While boys have been documented as having three times the rate of visual perceptual difficulties as girls, recent research has questioned this gender difference suggesting that reversal errors in girls are often overlooked.16,17

Identifying boys and girls at risk of experiencing increased levels of academic difficulties is not only important for their academic functioning but for general functioning.18 Studies have determined that older children and adults with academic and learning difficulties are more prone to behavioural difficulties, educational dropout, suicide19 and anxiety.20,21

Teachers have long identified legibility as an essential criterion when evaluating children’s handwriting abilities.22 In this regard, visual perceptual skills (e.g., visual discrimination and visual-spatial skills) have been identified as important cognitive skills that children need in order to write legibly (i.e., constructing letters with the correct form, consistent sizing, positioning and directional orientation).23 Visual perception comprises a number of subtypes, including (but not limited to), visual discrimination and visual-spatial skills. Visual perception is the ability to conceptually assimilate, understand and interpret the visual sensory stimulus presented and to develop meaning from this information for use in verbal or physical output.24 Visual discrimination is a component of visual perception which enables the person to expedite the differentiation of similarities and differences of visual input.25-27 Visual discrimination precedes the ability to differentiate changes in direction which, in turn, assist visual-spatial skills.27 Visual-spatial skills enable children to perceive the position of objects related to their own body or other objects, such as linking the direction of an ‘r’ in relation to the line on the paper.28-30 At the stage when children are entering school, visual perception is at the optimum period of development (four and a half to seven years), but may continue up to 12 years of age. It is thus at this stage that it is important to identify and address potential difficulties in visual perceptual skills that may influence the learning of letters, numbers, words and comprehension.31,32

In order to perform visual perceptual skills (i.e. visual discrimination and visual-spatial skills) children need to have a conceptual understanding of colours, shapes, directionality (up, down, left, right, etc.), distances and sizes, and to be able to identify the finer distinguishing features of different objects.33 For example, research has shown that children characteristically find it hard to identify letters that have less distinguishing features and that are visually similar to other letters.34

The visual processing model is a model explaining how visual perception occurs by means of input, throughput and output. According to the visual processing model, the visual cognitive component of this process involves brain throughput of the sensory information received from the eyes (input). The processed information is sent to other brain regions and body parts for an action response (output).32 Visual cognitive processes identify the unique features of the visual information, and they are then analysed so that meaning can be assigned to the unique identifying features of stimuli recorded by the eyes.35 Difficulties with the visual cognitive processes, such as visual discrimination and visual-spatial skills, negatively impact a child’s ability to identify the correct orientation of numbers/letters and contribute to reversals when reading and writing.25

It is essential for developers of educational and psychological assessments to meet recommended standards substantiating the reliability and validity of their assessment tools.34 Thus, studies that explore and demonstrate the reliability of each newly developed assessment are considered critical to establishing the instrument’s validity.34 This study is the first to examine the validity of one such assessment, the Richmond Reversal Rating (RRR) assessment. Spe-
Table I: Demographic information of the 76 participating children

<table>
<thead>
<tr>
<th>Participants</th>
<th>Grade 1</th>
<th>Mean Age</th>
<th>Grade 2</th>
<th>Mean Age</th>
<th>Grade 3</th>
<th>Mean Age</th>
<th>Total</th>
<th>Mean Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>17</td>
<td>6y 8m</td>
<td>7</td>
<td>7y 9m</td>
<td>12</td>
<td>8y 9m</td>
<td>36</td>
<td>7y 9m</td>
</tr>
<tr>
<td>Female</td>
<td>15</td>
<td>6y 6m</td>
<td>15</td>
<td>7y 6m</td>
<td>10</td>
<td>8y 6m</td>
<td>40</td>
<td>7y 6m</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>6y 7m</td>
<td>22</td>
<td>7y 8m</td>
<td>22</td>
<td>8y 7m</td>
<td>76</td>
<td>7y 6m</td>
</tr>
</tbody>
</table>

South African Journal of Occupational Therapy — Volume 48, Number 3, December 2018

© SA Journal of Occupational Therapy
Table II: Details for RRR subscales content and scoring

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Visual perceptual skill</th>
<th>Content</th>
<th>Maximum score</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Visual discrimination</td>
<td>Upper case letters</td>
<td>30</td>
</tr>
<tr>
<td>II</td>
<td>Visual discrimination</td>
<td>Lower case letters</td>
<td>36</td>
</tr>
<tr>
<td>III</td>
<td>Visual discrimination</td>
<td>Numbers</td>
<td>20</td>
</tr>
<tr>
<td>IV</td>
<td>Spatial orientation</td>
<td>Letters and numbers</td>
<td>37</td>
</tr>
<tr>
<td>V</td>
<td>Form constancy</td>
<td>Letters and numbers</td>
<td>18</td>
</tr>
<tr>
<td>VI</td>
<td>Sequencing</td>
<td>Letters and numbers</td>
<td>36</td>
</tr>
<tr>
<td>VII</td>
<td>Figure ground</td>
<td>Letters in words</td>
<td>34</td>
</tr>
<tr>
<td>VIII</td>
<td>Figure ground</td>
<td>Numbers in calculations</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Overall accuracy score</td>
<td></td>
<td>226</td>
</tr>
</tbody>
</table>

Spatial Awareness Skills Program Test (SASP)

Participants’ visual spatial ability was assessed using the Spatial Awareness Skills Program Test (SASP), which is suitable to assess children aged 4–10 years. The SASP measures children’s ability to use spatial awareness to near-copy up to 15 line shapes, with increasing level of difficulty. The assessment was administered in accordance with the manual instructions. The SASP has a reported average internal consistency of .76 and an inter-rater reliability of .96. Australian norms were used for scoring the SASP. The Australian norms provide clearer definitive expected levels of achievement. The norms were developed on 881 children (446 girls, 435 boys) between 5 and 10 years, the majority in Pre- primary through Grade 1 (675). The Australian norms provided derived scores in terms of percentiles for each age and year group, thus providing clearer expectations than the original age/grade equivalent norms.

Data analysis

Data collected for each participant were recorded on an Excel spreadsheet and statistically analysed using IBM SPSS Statistics version 24. All assessments were completed in full, with no missing assessment information or scores. The following criteria were used to define the strength of the correlation coefficients: low = .00 to .25, fair = .26 to .50, moderate = .51 to .75, and good > .75. Throughout the report, a 95% confidence interval and a significance level of p ≤ 0.05 were used unless specifically stated otherwise.

The SASP manual provides the assessor with age equivalent level scores, in six-month intervals, for the interpretation of the assessment results; however, an Australian based study has provided percentiles in age and grade levels which were used in this study. Participant’s spatial awareness results were grouped in three ordinal groups by using the participants’ percentile score. These ordinal groups were categorised as: below average when the percentile score was below 19 for the year level; average when the percentile was 20 to 82 according to the year level; and above average when the percentile was 83 or more according to the grade level. The three ordinal SASP groups were used to compare and analyse the significance of mean differences and correlation coefficients with the RRR scores.

RESULTS

Descriptive information for the RRR accuracy scores and SASP scores are provided in Table III on page 27 and indicate a negative skew on the results of the RRR raw scores and an approximate normal distribution of SASP raw scores.

Three ordinal groups created from the SASP results provided known groups’ validity, namely below average, average, and above average. In Year 1, ten participants were categorised as below average, 17 as average and five as above average; in Year 2, three were below average, 13 were age average and six were above average; while in Year 3, five participants were classified as below average, 14 as average and three as above average.
Due to the ordinal nature of the SASP grouped results, the RRR overall raw scores were analysed using non-parametric statistical analysis. The RRR overall accuracy scores were ranked with mean rankings of 28.14; 39.00, and 50.25 for below average, average and above average groups respectively. The ranked results were compared using the Kruskal-Wallis test to determine the significance of differences between the three independent ordinal SASP groups. This analysis allows indicates that the RRR ranked overall scores were significantly different between the SAPS grouped results, $H(2) = 7.956, p = .019$, thus indicating that the RRR has discriminatory ability in visual spatial ability levels. The Jonckheere’s Terpstra Test adjusted $p$-values of the RRR and SASP groups revealed a significant trend in the ranked RRR overall mean scores between participants in the below average and above average groups of $p = .008$, but not between the other groups (below average level and average $p = .119$ and average to above average $p = .147$).

### Correlations

The RRR ranked overall scores were correlated with the SASP percentile results using the non-parametric two-tailed Spearman’s correlation coefficient. Based on the results from this analysis, a significant fair positive correlation ($r_s = .433, p = .000$) between the RRR ranked overall scores and the SASP percentile results was found. Table IV above outlines the Spearman’s correlation coefficient results between the RRR ranked subscales and the SASP groups.

The RRR ranked overall scores were correlated with the SASP raw scores using the non-parametric two-tailed Spearman’s correlation coefficient. Based on the results from this analysis, a significant moderate positive correlation between the RRR ranked overall scores and the SASP raw scores, ($r_s = .666, p = .000$) was revealed. The Spearman’s correlation coefficient results between the RRR ranked subscales and the SASP raw scores demonstrate a significant moderate positive correlation between all the RRR ranked subscale scores and the SASP ranked raw score except for RRR Form Constancy subscale V, which demonstrated a low positive, but significant, correlation coefficient (see Table IV above).

Additional data analysis, using the Kruskal-Wallis test and the Jonckheere’s Terpstra test, was performed to determine the significance of the mean results between school years for both groups.

### Table III: RRR and SASP raw scores

<table>
<thead>
<tr>
<th>RRR overall raw scores</th>
<th>Year 1 $(n_1 = 32)$</th>
<th>Year 2 $(n_2 = 22)$</th>
<th>Year 3 $(n_3 = 22)$</th>
<th>Total $(N = 76)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum score (minimum 0)</td>
<td>128</td>
<td>164</td>
<td>137</td>
<td>128</td>
</tr>
<tr>
<td>Maximum score (maximum 226)</td>
<td>225</td>
<td>224</td>
<td>224</td>
<td>225</td>
</tr>
<tr>
<td>Range</td>
<td>97</td>
<td>60</td>
<td>87</td>
<td>97</td>
</tr>
<tr>
<td>Median (Mdn)</td>
<td>188.50</td>
<td>209.0</td>
<td>215.0</td>
<td>204.0</td>
</tr>
<tr>
<td>Means ($\bar{X}$)</td>
<td>184.91</td>
<td>206.95</td>
<td>207.45</td>
<td>197.82</td>
</tr>
<tr>
<td>Standard Deviation (SD)</td>
<td>25.905</td>
<td>14.630</td>
<td>21.289</td>
<td>24.229</td>
</tr>
<tr>
<td>Skewness</td>
<td>-.596</td>
<td>-1.590</td>
<td>-2.294</td>
<td>-1.211</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>-.340</td>
<td>2.613</td>
<td>5.511</td>
<td>.779</td>
</tr>
</tbody>
</table>

### Table IV: Spearman’s correlation coefficient between RRR and SASP scores

<table>
<thead>
<tr>
<th>SASP Grouped Scores $(N = 76)$</th>
<th>SASP Ranked Percentiles $(N = 76)$</th>
<th>SASP ranked Raw Scores $(N=76)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RRR Ranked Overall .325** ($p = .004$)</td>
<td>.433** ($p = .000$)</td>
<td>.666** ($p = .000$)</td>
</tr>
<tr>
<td>RRR Ranked Subscale I .247* ($p = .031$)</td>
<td>.302** ($p = .008$)</td>
<td>.498** ($p = .000$)</td>
</tr>
<tr>
<td>RRR Ranked Subscale II .312** ($p = .006$)</td>
<td>.396** ($p = .000$)</td>
<td>.588** ($p = .000$)</td>
</tr>
<tr>
<td>RRR Ranked Subscale III .282* ($p = .013$)</td>
<td>.394** ($p = .000$)</td>
<td>.578** ($p = .000$)</td>
</tr>
<tr>
<td>RRR Ranked Subscale IV .337** ($p = .003$)</td>
<td>.423** ($p = .000$)</td>
<td>.581** ($p = .000$)</td>
</tr>
<tr>
<td>RRR Ranked Subscale V .077 ($p = .506$)</td>
<td>.162 ($p = .163$)</td>
<td>.281* ($p = .014$)</td>
</tr>
<tr>
<td>RRR Ranked Subscale VI .252* ($p = .028$)</td>
<td>.297** ($p = .009$)</td>
<td>.457** ($p = .000$)</td>
</tr>
<tr>
<td>RRR Ranked Subscale VII .252* ($p = .028$)</td>
<td>.361** ($p = .001$)</td>
<td>.587** ($p = .000$)</td>
</tr>
<tr>
<td>RRR Ranked Subscale VIII .313** ($p = .006$)</td>
<td>.441** ($p = .000$)</td>
<td>.600** ($p = .000$)</td>
</tr>
</tbody>
</table>

* Correlation $p < .05$, ** correlation $p < .01$
assessments. In both the RRR and the SASP, there was a significant difference between Year 1 and Year 2 (RRR $p = .003$; SASP $p = .007$) and between Year 1 and Year 3 (RRR $p = .000$; SASP $p = .000$), however the significance between Year 2 and Year 3 (RRR $p = .000$; SASP $p = .515$) was not significant.

**DISCUSSION**

The visual perceptual frames of reference used by occupational therapists (i.e. visual perceptual skills, including visual-spatial and visual discrimination skills) develop in two ways, namely, through natural maturation and/or learning opportunities. Based on this theory, increasing mean scores as the children progress through the school years are expected on both the RRR and SASP assessments due to their underlying constructs. The results from the study reflect this development with increasing ranked mean scores from Year 1 to Year 2, and Year 2 to Year 3 for both assessments, with significant differences between Year 1 and Year 2, and between Year 1 and Year 3 for both assessments.

The results indicated no significant difference between the ranked RRR and SASP mean scores for participants between Year 2 and Year 3. As the study’s Year 2 participants ranged in age from 7.02 to 8.01 years, these results support previous observations that visual perceptual skills improve with age, but become more stable and reach developmental peak by approximately age 7 years. After age 7 years, visual perceptual skills will increase minimally through the natural maturation process. Letter reversals observed at later ages are considered a reversal error and targeted interventions will be necessary to address the deficits.

Four Year 3 participants obtained a RRR overall score of $< 200$ and, as reported by the parents, three of these four have been diagnosed with a specific learning difficulty and order reversal difficulties in order to assist with targeted inter-
ventions based on the type of reversal difficulties recorded. For example: per Victorian Modern font (b, i, l, o, n, r, t, a, d, z) and per Queensland beginner font (b, i, l, o, p, r, t, a, d, z).

To reduce the impact these differences in the fonts could have on this study's RRR results, participants were offered and provided with, verbal assistance to name the letter or word when requested by the examinee. Most of the participants noted they were aware of different fonts used to write letters, often commenting that the Victorian Modern font looked like the writing style used by their parents or older siblings. Despite this, the font differences may have had a yet unquantified impact on the results for particular subscales items. Additional analysis to explore the potential impact on each subscale item has yet to be performed.

The above-mentioned limitations could have impacted on the study’s results to some extent and, therefore, they should be carefully considered when interpreting the results. In addition this study was non-experimental in nature, which intrinsically limited the interpretation (relationship between variables only, no cause-and-effect evidence) that can be associated with the results.

**IMPLICATIONS**

The results from this study provide additional evidence for the convergent validity of the RRR scores in relation to young school-aged children’s visual-spatial abilities. For the clinician, the results demonstrated additional evidence for the validity and potential use of the assessment to determine which children experience letter-number reversal difficulties in order to assist with targeted interventions based on the type of reversal difficulties recorded. For the children struggling with letter-number reversals when reading or writing, the results provide additional support for the ability of the RRR assessment to identify the specific underdeveloped visual motor component for comparison.

The limited timeframe available to approach and recruit a private school to participate in the study made it impractical to be overly selective about the participating school based on the writing font taught by the school. There are a number of differences between the lower case letters used in Australia’s Victorian Modern Cursive and Queensland Beginner font, the font taught to the children that participated in this research project. For example: per Victorian Modern font (b, i, l, o, n, r, t, a, d, z) and per Queensland beginner font (b, i, l, o, p, r, t, a, d, z).
perceptual skills that are contributing to their reversal difficulties. It is recommended that future researchers focus on using longitudi-
dinal, experimental research designs with a sample size that meet the recommended optimal size (by gender, year and diagnosis) to explore and provide increased level of evidence for the assessment’s reliability and validity. The RRR participants’ results must be observed and analysed over time to refine the interpretation of the assessment results. In addition, further research should focus on the use of the parallel forms that have been created since this project, using Queensland Beginners and Foundation print fonts. The initial concept of this test came from the researchers’ clinical observations working in remedial schools in South Africa. The concept has been developed, tested and finalised primarily on children in Perth (Australia), however due to the nature of the itinerant population in Perth, South African children are included in the test samples among many other nationalities. Further research on diverse populations in other countries such as South Africa is still required to develop a robust assessment with strong external validity.

REFERENCES

1. Brooks AD, Berninger VW, Abbott RD. Letter naming and letter writing reversals in children with Dyslexia: Momentary inefficien-
5. Heydorn BL. Symbol reversals, reading achievement and handed-
7. Moyer SB, Newcomer PL. Reversals in reading: diagnosis and re-
12. Boon HC. Relationship of left-right reversals to academic achieve-
13. Cheung P, Poon M, Leung M, Wong R. The Developmental Test of Visual Perception-2 normative study on the visual-perceptual func-
tion for children in Hong Kong. Physical & occupational therapy in class-
room. Arizona: Therapy Skill Builders (A Division of Psychological Corporation); 1991.
15. Richmond J, Taylor M, Evans S. Developing bilateral and spatial con-
18. Taylor M, Houghton S, Chapman E. Primitive reflexes and attention-
19. Morgan PL, Farkas G, Tufts PA, Sperling RA. Are Reading and Be-
22. Nelson JM, Harwood H. Learning Disabilities and Anxiety: A Meta-
30. Barnes MA, Raghubar KP. Mathematics development and difficul-
tion; 2014.
tion; 2014.


Corresponding author
Dr Janet Richmond
Email: j.richmond@ecu.edu.au