Colour Vision and Distant Visual Acuity of Elite and Junior Cricketers: Educational and Sporting Implications for Students

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Evidence suggests male children and adolescents spend increasingly more of their leisure time engaged in indoor activities such as the viewing of computer or television screens. Consequently, time spent on outdoor activities that require distant visual acuity or acute, sharp vision is considerably less. Furthermore, 8% of the male population are known to have colour vision problems. A study was conducted to compare the colour vision and visual acuity of elite male cricketers, junior male cricketers, and male students from a primary, secondary and tertiary school context who had not received intensive cricket training. This study aimed to determine whether visual acuity is higher than normal in elite cricketers and explored the relationship between colour vision deficiency and participation in cricket. Findings suggest that males involved in outdoor sports such as cricket that require constant use of distant vision, perform significantly better than the norm on visual acuity tests. In addition, male students in primary, secondary and tertiary school settings with known colour vision deficiencies do not participate willingly or effectively in sports that require normal colour vision. This paper will address implications for male students with colour vision or visual acuity problems who participate in sport or educational activities in classroom settings.

Background
In a modern world an increased availability of technology has resulted in human beings becoming more dependent on their use for a range of learning and leisure activities. Computer and television are accepted technological mediums frequently used by adults and children alike in most households. When people interact with such technologies they rely on near vision skills and fail to exercise or apply their distant vision capabilities. Furthermore, new technologies frequently rely on colour to communicate messages that creates a whole new range of difficulties for users with colour vision deficiencies. In addition, use of technologically-based educational and entertainment aids encourages a more sedentary way of life which has placed emphasis on the negative health issues attributed to their use. It remains to be seen what long term influences the use of technological aids such as computer and television will have on the vision capabilities and health conditions of frequent users.

The research reported here looks at these modern world challenges from the perspective that the enhanced visual motor skills of elite sportsmen such as cricketers might hold new insights into ways to better cater for students who interact frequently
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with technological aids and those who present with low vision or colour vision deficiencies. Therefore, the researchers chose to study the advanced optical abilities of cricket players in the hope of addressing the needs of students with vision problems and their educators working within learning contexts.

Knowledge of the game of cricket tells us that when a batsman faces a bowler in a cricket match, he has to respond to balls of varying speed, height and direction. A fast bowl can achieve speeds to 40 m/s and a slow ball can spin and arrive in an unpredictable direction. The visual motor skills of the batsman are crucial for successful play. He may have less than half a second after the ball leaves the bowler's hand to decide when and where the ball will arrive. Research informs us that the greatest demand on a batsman's attention occurs immediately before a ball is released by a bowler (Barras, 1984, as cited in Barras, 1988, p. 25). Furthermore, "skilled batsmen are more efficient than unskilled batsmen in predicting the line of a bowled delivery" (Barras, 1982, as cited in Barras, 1988, p. 16). Batsmen have been found to fixate their eyes at the point of release of a ball and wait for a bowler's hand and ball to actually appear (Barras, 1988).

A recent study which recorded eye movements or the foveal gaze of three batsmen on a medium pace ball found that batsmen monitored the release of the ball, anticipated where the ball would bounce, then followed the trajectory for a short time after the bounce. The authors concluded that years of practice have given top-class batsmen the high-order skill of using the position and timing of the bounce to predict the time and height of bat-ball contact (Land & McLeod, 2000). It is apparent that batsmen would benefit from good visual acuity for both the release of the ball at a distance and also for the nearer ball at bounce point and afterwards. The study reported here hoped to build on such findings to determine whether visual acuity is higher than normal in elite cricketers and to explore the relationship between colour vision deficiency and participation in cricket.

Visual acuity

In broad terms, visual acuity is a measure of the ability to see fine detail, with the central region of the human retina, the fovea, giving the best detail or high acuity. This region is packed with cones; one of the two types of light-receptor cells in the retina. Because the visual system transforms the light reaching the retina to perceptions of shape, movement and pattern, the one-to-one relationship between the optic nerve fibres leading to the cortex and the cone receptors in the central fovea is of great importance for acuity. This allows much higher discrimination than at the periphery where there is not a one-to-one relationship but instead many receptors that are connected to each nerve fibre.

It has been found that results of visual acuity tests depend not only on the characteristics of the individual optical and anatomical system but also on factors such as experience, training and age. There is an improvement in acuity during early childhood as ability to see fine detail depends on ability to keep eyes fixated, but by about the age of nine years, the visual acuity of children is near the norm for adults.

There are some reports of people with better than normal acuity. A high frequency of good visual acuity has been found in Afro-Americans and the indigenous people of Brazil, the Solomon Islands, and Australia. Taylor (1980) investigated the visual acuity of
adult Australian Aborigines and Europeans and found significant differences between the groups. The binocular acuities for Aboriginal males ranged from 6/1.5 to 6/7.5. For Aboriginal females, the acuities ranged from 6/1.75 to 6/9.5. The binocular acuity for European males ranged from 6/1.9 to 6/15, and for European females from 6/2.4 to 6/9.5. Three Aborigines were found with acuity of 6/1.5. No European attained this acuity. It is plausible that dependence on good vision for survival and training received from an early age to detect and recognise distant small objects could be involved in producing good visual acuity. It is not unusual for highly trained observers to show good acuity for tasks on which they have been trained or on similar ones. For example, aircraft crew members (Boisson & Lafontaine, 1973) and professional baseball players (Laby et al., 1996) have been found to have good visual acuity. Of the latter, 1.7% of eyes tested had an acuity of 6/3 or better, and 42% had an acuity of 6/4 or better. It is apparent that experience and cognitive factors play a major role in influencing ability to detect fine detail. Therefore, human visual acuity is not a product solely of the optical system.

Colour vision

All known colour vision systems are based on the presence of two or more visual pigments or kinds of receptors differing in spectral sensitivity. In humans, normal colour vision depends on three types of cone system. One has peak sensitivity for long wavelengths (red), the second for middle wavelengths (green), and the third for short wavelengths (blue). A fourth type of pigment occurs in the rods and underlies colourless vision in low light.

One of the original early writers with an interest in the evolution of human colour vision was Ladd-Franklin (1892). She proposed that red/green discrimination had evolved relatively recently and was superimposed upon a much more ancient form of dichromatic colour vision, which enabled animals to distinguish long and short wavelengths, or red and blue colours. Despite the biological advantages of trichromacy and evidence of an evolutionary trend towards trichromatic colour vision in humans, some humans are limited in this respect. Limitation may be shown as "a confusion of, or blindness to, one or more of the chromatic colours" (Litton, 1979, p. 438). Deficiency in colour vision may be caused by acquired brain damage, but most cases are of congenital origin (Litton, 1979).

A lack of one of the three types of colour-sensitive cone system leads to dichromatic colour vision. A person is described as a protanope, deutanope or tritanope after 1st (long wavelength), 2nd (middle wavelength), and 3rd (short wavelength). It is more common to find a reduction rather than a complete absence of sensitivity to one system. This is called anomalous colour vision. Protan, deutan, and tritan are inclusive terms used to indicate that there is either absent or reduced sensitivity in one of the colour sensitive systems.

Until recently, the genetic basis of colour vision was inferred from measurements of family groups. In the last decade, however, genes for visual photopigments have been isolated and sequenced and it has been well established that protanopia, deutanopia and the red-green forms of anomalous trichromacy are inherited as totally sex-linked recessive
characteristics (DeMarco, Pokorny, & Smith, 1992; Nathans, Thomas, & Hoggins, 1986). Reports of Caucasian males indicate that about 8% have defective colour vision in comparison with about 0.4% of females. More detailed analysis has shown that approximately 5% of US males have deuteranomalous trichromacy, while 1% have protanomalous trichromacy (DeMarco, Pokorny, & Smith, 1992).

Red green vision colour deficiencies are more frequent among males than females because the genes for both long-wavelength and middle-wavelength sensitive pigments are carried on the q-arm of the X chromosome, whereas the genes for short-wave cone pigments are on chromosome 7 and those for rods are on chromosome 3. Long-wavelength and middle-wavelength genes are not only on the same chromosome, but in the same region and of similar amino-acid sequence.

The presence of colour has become an important variable when one considers the impact it can have on students’ educational outcomes and social participation including the playing of sport. Many educational materials such as graphics, charts, maps, and signs used for the development of concepts across subject areas, rely on the use of colour. As a result, implications of colours in learning chemistry have been noted (Diehl, Johnson, Markuszewski, & Moore, 1985), while Kruglak and Campbell (1983) demonstrated the importance of colour discrimination in enhancing the learning of physics at the school level. Reid, Beveridge and Wakefield (1986) showed that not only did colour improve children’s observation scores when working from a biological picture, but that even when items which were colour-specific were removed from the overall tally of scores, coloured pictures still induced significantly higher observation scores than their monochrome counterparts. In addition, perceptual difficulties have been reported for people with colour vision deficiencies. Cavanagh and Anstis (1991) demonstrated that colour makes an important contribution to the perception of motion, while Mollon (1989) stated that people with colour vision deficiency may have difficulty detecting objects of certain colours or segmenting elements that belong together for characteristics such as lightness, shape, texture, or colour. These findings have important implications for students with colour vision deficiencies working in educational settings where sometimes they have been incorrectly labelled as learning disabled or emotionally disturbed (Gnadt & Amos, 1992; Hurley, 1994; Wilkinson, 1992). Outside the classroom, these deficiencies may preclude effective participation in sports and recreational activities such as cricket.

**Description of the project**

An earlier pilot study conducted by Tourky and Bartlett (2000) highlighted difficulties secondary school students with colour vision deficiencies experience when they engage in sporting activities with their peers. This study acknowledged a need for further research on the topic. Hence, the research reported here compared professional adult and junior cricket players to non-cricket players of the same age to determine if there were differences with respect to their distant visual acuity and colour vision. In order to determine the effect of intensive cricket practice, the visual acuity of participants was examined to see whether elite cricket players showed a level of acuity higher than the norm and higher than junior players. Colour vision screening occurred to determine
whether colour deficiencies are less prevalent in males who are in professional or junior teams. Members of the national Queensland cricket team, The Bulls, were approached to become participants in the research project. Professional adult cricketers from this team were made available for visual acuity and colour vision screenings. In addition, The Valley Cricket Club and others consented to allow their senior and junior cricket players to be available for the same screening procedures.

**Method**

**Participants**

Four groups of participants were selected for inclusion in this study. Group 1 comprised adult male elite cricketers over the age of 18 years. Group 2 comprised adult male non-cricketers over the age of 18 years who were students at a Brisbane university. Group 3 comprised junior male cricketers under the age of 18 years who were training in various cricket clubs throughout Brisbane. Group 3 was further divided into two subgroups. Subgroup 3A comprised junior male cricketers who were 13-17 years of age. Subgroup 3B comprised junior male cricketers who were 9-12 years of age. Group 4 comprised male non-cricketers under the age of 18 years who were students from primary and secondary schools in Brisbane. Group 4 was further divided into two subgroups. Subgroup 4A comprised male non-cricketer secondary students who were 13-17 years of age. Subgroup 4B comprised male non-cricketer primary and secondary school students who were 9-12 years of age. All four groups and their accompanying subgroups were tested and analysed for visual acuity and colour vision. Elite and junior male cricket players were then compared to male non-cricket players of the same age to determine if there were differences with respect to visual acuity and colour vision.

**Procedure**

Elite and junior cricketers were enrolled in the study once relevant sporting organisations, cricket clubs and individual players had provided their consent. All primary and secondary school students were included after relevant school administrators, parents and the students themselves had given consent. University student participants volunteered to take part in the study. Aims and method of the study were shared with all participants along with a consent form that was signed individually by each participant. This provided an opportunity for participants to be briefed further on the study before giving their consent to become involved.

Visual acuity and colour vision assessments were carried out individually with all participants. The Snellen chart was used for assessment of distant visual acuity. Colour vision was screened using the Ishihara (1990) colour blindness test.

**Instruments**

*Snellen chart*

The Snellen chart was used to measure the visual acuity of all participants. Letters on this chart are arranged in rows of decreasing size and the smallest letter recognised correctly determines visual acuity. Construction of the letters is based on the angle of resolution at a specified distance of observation. The threshold for normal angle resolution is
1 minute of arc, so at each distance, letters are constructed as a square subtending 5 minutes of arc with each limb subtending 1 minute. The overall size of letters is therefore five times the width of each limb. At a distance of 6 metres, a letter of 8.73 mm overall size with limbs of 1.75 mm satisfied these requirements. If a person identified letters of this size at 6 metres, visual acuity was expressed as 6/6. If, at a distance of 6 metres, the person could identify the row of smaller letters which have an angle of resolution of 1 minute at 4.5 metres, visual acuity was higher for them and expressed as 6/4.5. There is an inverse relationship between distance from the stimulus and visual angle, so in this case, at 6 metres, the angle of resolution for this observer would have been 45 seconds.

Various changes have been made to the Snellen chart over the years as some letters cannot be drawn to fit the proposed dimensions. However, the conventional threshold for normal angle resolution is still taken to be 1 minute of arc. The assumption that all letters are equally recognisable and familiar to all observers has also led to changes in the chart so that the letters most difficult to recognise are distributed across the rows of varying size.

Environmental conditions for the four groups of participants were maintained when screening for distant visual acuity. Distant visual acuity tests were conducted outdoors on clear days when the sky was not cloudy. The Snellen chart was positioned at eye height for all participant groups and distances were marked at 1 metre intervals from 6 to 20 metres. Each participant began at a distance of 20 metres and moved in 1 metre at a time until they could see the second bottom line of the chart (designated 6) clearly. They then read the line out loud to the assessors.

**Test for colour blindness (TCB: Ishihara, 1990)**

The standard TCB test was used to measure the colour vision of all participants. This test has 38 plates, 25 with numerals and 13 with pathways to be traced by young or non-verbal persons. Abbreviated versions of the test are available, but a complete edition was used for this study. A survey of the accuracy of various tests led Birch and McKeever (1993) to recommend the 38 plate edition rather than a concise edition. These authors concluded that the TCB test was a highly efficient test of colour blindness that could be used for children from about 3 years of age. Other studies have reported good test-retest reliability and high validity. The TCB test is also preferred over other tests because it is less sensitive to viewing distance and viewing duration.

The TCB test consists of 25 white cards where dots of different shades of red and green have been arranged in patterns on the cards. A person with normal colour vision reports a certain series of numbers, while a person with red-green deficiency reports different numbers in response to the same plates. For example, to a person with normal colour vision, plate two the number 8, was apparent as a red figure on a background of green dots. However, to a person with red-green colour deficiency, this number appeared as a number 3 since the missing part of the number 8 is made of red dots which are very slightly different in colour from the other dots. This results in confusion with the dots of the green background pattern. Therefore, the TCB test comprised a series of ingeniously arranged plates so that some figures were apparent to those with normal colour vision, and in others, numbers were apparent only to those with colour deficiency. If 17 or more plates were read correctly, colour vision was regarded as normal.
Environmental conditions for the four groups of participants were maintained when screening for colour vision using the standard TCB test. Colour vision screenings were carried out indoors. A distance of 2.5 metres from the window to the seated participant was set and natural light from windows was always kept to the right hand side of the person being screened. The plates were held 75 centimetres from the person and tilted so that the plane of the paper was at a right angle to the line of vision. Each participant was required to respond to each plate within 3 seconds.

Analysis
In order to determine the effect of intensive cricket practice, the visual acuity of each group was examined to see whether elite cricket players showed a level of visual acuity higher than the norm and higher than junior players. Elite and junior cricket players were compared with the same-age groups of males with respect to visual acuity levels and to previous cricket experience, that is, number of years playing cricket and frequency of practice. This comparison provided opportunities to explore whether there had already been an effect of experience on a cricket player's visual acuity level by junior ages. Elite and junior cricket players were also compared to non-cricketer males of the same age with regard to colour vision defects to determine whether colour deficiencies are less prevalent in males who are in elite or junior cricket teams.

Results
Visual acuity and colour vision results were recorded for all participants. Table 1 shows the number of participants from each group or subgroup who presented with particular visual acuity levels.

Table 1
Number of participants with particular visual acuity levels

<table>
<thead>
<tr>
<th>Visual Acuity</th>
<th>Group 1 Elite Cricketers 18+ years</th>
<th>Group 2 Non-cricketers 18+ years</th>
<th>Group 3 Junior Cricketers 13-17 years</th>
<th>Group 4 Subgroup 3a Non-cricketers 13-17 years</th>
<th>Group 3 Subgroup 3b Junior Cricketers 9-12 years</th>
<th>Group 4 Subgroup 4b Non-cricketers 9-12 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/1.75</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/2.5</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/3</td>
<td>25</td>
<td></td>
<td>17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/4</td>
<td>26</td>
<td></td>
<td>28</td>
<td>21</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>6/5</td>
<td>15</td>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6/6</td>
<td>12</td>
<td>10</td>
<td></td>
<td>21</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>6/9</td>
<td>17</td>
<td>10</td>
<td></td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>6/18</td>
<td>1</td>
<td>1</td>
<td></td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6/24</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>6/36</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
Group 1, elite cricketers aged 18 years and over, scored above average in visual acuity with scores ranging from 6/4 to 6/1.75. Three elite cricketers had scores of 6/1.75, 10 had 6/2.5, 25 had 6/3, and 26 scored 6/4. Group 2, non-cricketers aged 18 years and over, were found to have normal to near normal visual acuity ranging from 6/5 to 6/18 with correction. Fifteen of these university students had a visual acuity of 6/5, 12 had 6/6, 17 had 6/9, and 1 student was found to have a visual acuity of 6/18. Further investigation was recommended for this student. Group 3, subgroup 3A, comprised the junior cricketers who ranged in age from 13-17 years. This group also scored above the average for visual acuity with scores ranging from 6/4 to 6/2.5. Six junior cricketers aged 13-17 years of age were found to have a visual acuity of 6/2.5, 17 had 6/3 and 16 had 6/4. Group 4, subgroup 4A, comprised the non-cricketer 13-17 year old secondary school students. Most of these participants were found to have normal to near normal visual acuity ranging from 6/5 to 6/9. Twenty-eight students were found to have a visual acuity of 6/5, 31 had 6/6 and 10 had 6/9. Four students were found to have less than normal visual acuity. One had a visual acuity of 6/18, 2 had 6/24 and 1 had 6/36. These 4 students were informed and were able to take action where they sought further advice for refractive corrections. Group 3, subgroup 3B, comprised the junior cricketers aged from 9-12 years of age. Participants from this group all scored above the average for visual acuity with scores from 6/3 to 6/5. Thirteen junior cricketers aged between 9-12 years had a visual acuity of 6/3, 18 had 6/4 and 21 had 6/5. Group 4, subgroup 4B, comprised non-cricketer primary and secondary school students aged 9-12 years of age. Most of these students were found to have normal to near normal visual acuity ranging from 6/5 to 6/9. Twenty students had a visual acuity of 6/5, 16 had 6/6 and 12 had 6/9. Four students were the exception. One had a visual acuity of 6/18, 2 had a visual acuity of 6/24, and 1 a visual acuity of 6/36. The schools and parents of these students were notified so further action could be taken.

Table 2 shows the number of participants from each group or subgroup who presented with colour vision deficiencies.

<table>
<thead>
<tr>
<th>Colour Vision</th>
<th>Group 1 Elite Cricketers 18 + years</th>
<th>Group 2 Non-cricketers 18 + years</th>
<th>Group 3 Subgroup 3A Junior Cricketers 13-17 years</th>
<th>Group 4 Subgroup 4A Non-cricketers 13-17 years</th>
<th>Group 3 Subgroup 3B Junior Cricketers 9-12 years</th>
<th>Group 4 Subgroup 4B Non-cricketers 9-12 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red/green mild</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>9</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Red/green strong</td>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Yellow/blue mild</td>
<td></td>
<td></td>
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<tr>
<td>Yellow/blue strong</td>
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</tr>
<tr>
<td>Total colour deficiency</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Table 2: Number of participants with colour vision deficiencies.
Among Group 1, elite cricketers aged 18 years and over, only 1 cricketer was found to have a mild red/green deficiency. When questioned, this player was found to play at both national and international cricketing levels, but was only ever selected in international one day cricket games where a white ball was used and not test matches where a red ball was used. In addition, results suggested that other elite players showed a preference for the use of a white ball during cricket matches. One player stated, “It takes longer to recognise a red ball on the grass than a white ball.” Three of the non-cricketer university students aged 18 years and over from Group 2 were found to have a mild red/green colour deficiency. All junior cricketers from Group 3, subgroup 3A, were found to have normal colour vision. Four 13-17 year old students from Group 4, subgroup 4A, were found to have a strong red/green colour vision deficiency, 1 a mild red/green deficiency, and 1 had total colour deficiency. In Group 3, subgroup 3B, only 1 junior cricketer who was 9 years of age was found to have a mild yellow/blue colour vision deficiency. Four 9-12 year old non-cricketer students from Group 4, subgroup 4B, were found to have colour vision deficiencies. Three of these students had a mild red/green deficiency and 1 had a strong red/green deficiency. The student with the strong red/green deficiency commented on difficulties he experienced when playing cricket with his peers saying, “I like to play cricket, but I can’t see the ball on the lawn. They don’t pick me.” He later clarified this statement by offering that although he could identify a ball on a lawn; it took him a considerably longer amount of time to see the ball than his peers. These four students were found to be previously unaware of their colour vision deficiencies.

**Conclusion**

This paper reports on findings associated with the visual abilities of cricketers. Results suggest that elite cricket players do have a visual acuity higher than the norm and that cricket training improves the visual acuity of young players. This research has extensive implications for the use and improvement of distant visual acuity in general for all young people and in particular for those with low vision. Furthermore, this study supports the notion that colour vision deficiencies are more common in boys who do not participate in cricket. If cricket management would like to encourage enthusiasm for the sport among all young people, it would seem advisable for them not to forget the special needs of those with visual deficiencies. Further research may clarify whether males with colour vision deficiencies have been excluded, or exclude themselves, from cricket. In addition, research into colour vision deficient cricket players and the skills that contribute to their effectiveness as cricket players, may be beneficial. It is predicted that with minor adaptations to the game such as a change to the colour of ball used, a greater number of cricket players could reach higher standards of play. This fact is pertinent when one considers that a current major difference between one-day and test cricket matches is the colour of ball used, where a white ball is used for one-day matches and a red ball is used for test matches.

These findings have practical implications for educators working with colour vision deficient students in school settings. The researchers recommend that educators

(a) Conduct regular visual acuity and colour vision screenings with students so that appropriate accommodations can be applied;
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(b) Pay greater attention to the colour of balls used for sporting activities like cricket and avoid use of a red ball on a green lawn;

(c) Consider more carefully the colours they use to create classroom displays and avoid using colour combinations such as red/green and blue/yellow colours wherever possible;

(d) Provide explicit instruction into the use of appropriate colours for various objects of nature, particularly for early childhood students with colour vision deficiencies or total colour blindness. These students may need explicit assistance to determine the most appropriate colours to use when colouring grass, the sky, or animals of nature to avoid embarrassment. In addition, students with colour deficiencies may need to be given specific techniques to help them identify different coloured pencils such as the labelling of pencil ends with letters or shapes.

We strongly suggest that

(a) A red ball on a green lawn not be used in any sport; and

(b) For the purposes of eye health and health in general, the playing of sport is extremely important.

Acknowledgement

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References


