COMPUTERISED SCORING AND GRAPHING OF THE FARNSWORTH-MUNSELL 100 HUE TEST OF COLOUR VISION - A PROGRAM WRITTEN IN PASCAL

V Balakrishnan, P T K Chew

ABSTRACT
The Farnsworth Munsell 100 Hue test is the best test for diagnosing and assessing colour vision defects. A computer program written in Pascal which automatically scores, plots and analyses the results of the Farnsworth Munsell 100 Hue test is presented.

Keywords: Colour vision, psychophysical tests, Farnsworth-Munsell, computer, Pascal

INTRODUCTION

Colour vision testing is an essential part of any comprehensive clinical assessment of visual function. Various clinical tests have been designed and are used to varying extents depending upon availability and the user's familiarity.

The Farnsworth Munsell 100 Hue test is presently the 'gold standard' against which other tests are measured. It was originally designed to test colour discrimination of employees in the dye and paint industries. However, with time, it has been found to be extremely useful in the detection, diagnosis, qualitative and quantitative assessment of both congenital and acquired colour vision deficiencies.

The test consists of 84 plastic caps with different coloured tops which systematically sample the full range of colours perceptible by the human eye. Each cap is just distinguishable from its neighbour based on its hue. The 84 caps form a sequence which a 'normal' would be able to arrange with few mistakes. 'Abnormal' persons would make characteristic errors because they would have difficulty discriminating certain hues. The test would therefore reveal both the orientation and degree of the defect. It also facilitates classification of 'normals' into superior, average or poor colour discriminators. Furthermore, it is the best method presently available for the detection of early acquired colour vision defects.

Unfortunately, the test is laborious and time consuming calculations are needed to score and plot the results for interpretation. The typical patient would require around 10 to 15 minutes per eye to perform the test. However, the calculations could easily take 30 minutes. This has resulted in the test falling into disuse except in specialised centres(with 'cheap' trainee labour).

In Singapore, the most commonly used test of colour vision is the Ishihara pseudo-isochromatic plates which were designed for detecting significant congenital red-green defects. Unfortunately, it does not detect blue-yellow defects and is not a quantitative test, thus precluding its use in following a patient's progress. As acquired colour vision defects often in-

Department of Ophthalmology
National University of Singapore
Lower Kent Ridge Road
Singapore 0511

V Balakrishnan, M Med(Ophth), FRCSEd, FCOphth
Lecturer

P T K Chew, M Med(Ophth), FRCSEd, FCOphth
Lecturer

Correspondence to : Dr V Balakrishnan

volve the blue-yellow axis, complete reliance on the Ishihara plates defects does involve some risk.

The easy availability of microcomputers suggested that the drudgery of the Farnsworth Munsell test could be reduced if a user friendly and fast program was written. It was hoped that the savings of time would allow the test to be used on a wider basis and benefit patient care in so far as it allowed a more comprehensive assessment. This program is presently used by ophthalmic units in Singapore and Malaysia.

SUBJECT AND METHODS

The program was written in Turbo Pascal Version 5.5 and runs on any IBM compatible computer with a graphics adapter and an Epson compatible printer. This configuration allows it to be used on the majority of micro computer systems presently available.

The user is requested to input patient's name, age, date and eye being tested. Next the sequence of caps which the patient arranged is input. Thereafter, everything else is automated.

The following results are output:
Total error score
Red-green partial error score
Blue-yellow partial error score
Individual cap error scores

The statistical significance of the scores are also computed based on age matched norms established by Verriest et al[1]. The colour axis determination is made using the Smith's[2] method.

A polar graph is also plotted on screen which facilitates identification of the orientation of the colour deficiency. (See Fig 1 which shows a patient with a typical red-green defect).

The scores, statistical analysis and graph may all be printed for filing purposes. The program also stores the results for future reference and comparison.

DISCUSSION

There have been several attempts at automating the Farnsworth Munsell test in the past. Benzschawel[3] published a program written for the now obsolete Apple computer which calculated error scores and compared them to population norms. However, it did not plot the polar graph which has traditionally been used for interpretation.

Another program for the Apple computer was written in 1988 by us which addressed this deficiency[4].

Miguel Lugo et al[5] published a program in BASIC for the IBM PC which calculated error scores and plotted a polar graph. This program did not perform statistical analyses or calculate separate red-green and blue-yellow scores.

Our present program is the only one published written in Pascal which performs all the functions listed above. Its advantages are:
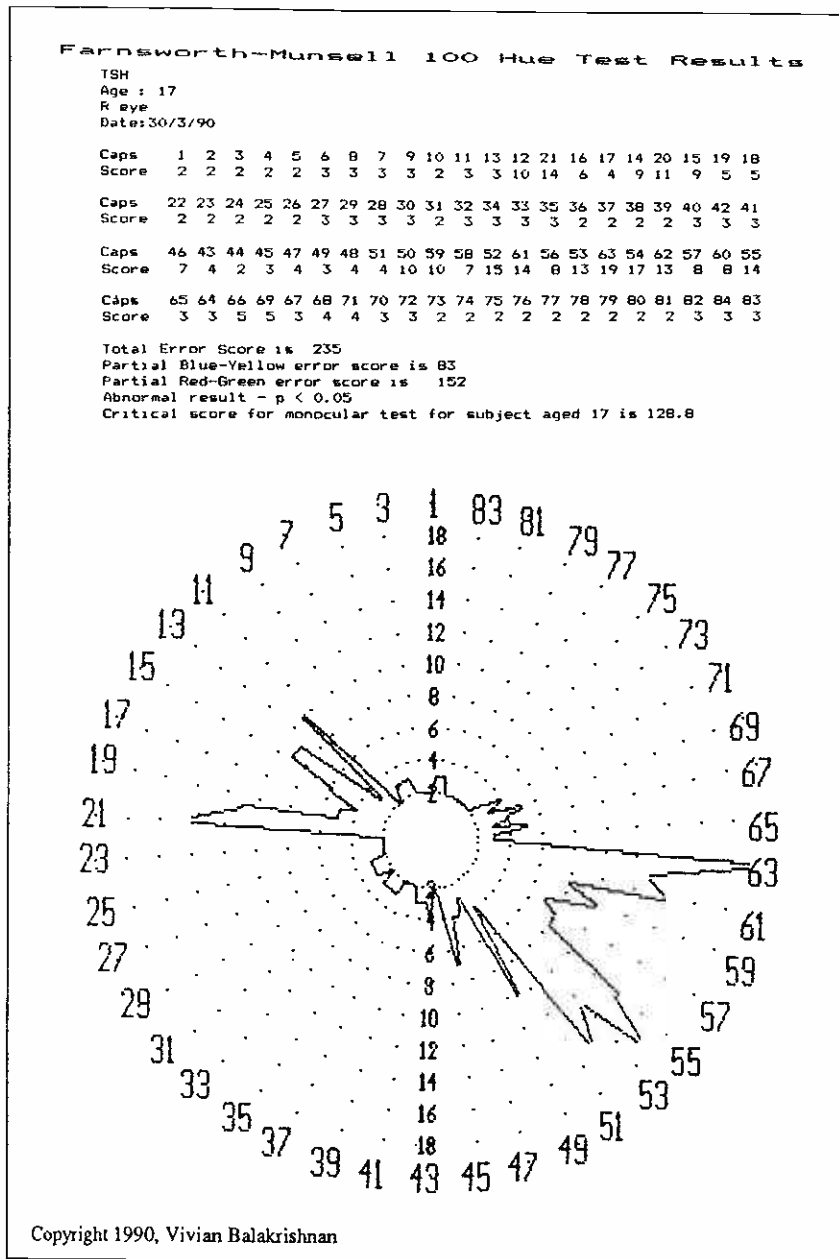
Fig 1 - Farnsworth - Munsell 100 Hue Test Result

```
Farnsworth-Munsell 100 Hue Test Results
TSH
Age : 17
R eye
Date:30/3/90

Caps    1   2   3   4   5   6   8   7   9  10  11  13  12  21  16  17  14  20  15  19  18
Score   2   2   2   2   2   3   3   3   3   2   3   3  10  14   6   4   9  11   9   5   5

Caps   22  23  24  25  26  27  29  28  30  31  32  34  33  35  36  37  38  39  40  42  41
Score   2   2   2   2   2   3   3   3   3   2   3   3   3   3   2   2   2   2   3   3   3

Caps   46  43  44  45  47  49  48  51  50  59  58  52  61  56  53  63  54  62  57  60  55
Score   7   4   2   3   4   3   4   4  10  10   7  15  14   8  13  19  17  13   8   8  14

Caps   65  64  66  69  67  68  71  70  72  73  74  75  76  77  78  79  80  81  82  84  83
Score   3   3   5   5   3   4   4   3   3   2   2   2   2   2   2   2   2   2   3   3   3

Total Error Score is  235
Partial Blue-Yellow error score is  83
Partial Red-Green error score is   152
Abnormal result - p < 0.05
Critical score for monocular test for subject aged 17 is 128.8
```

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— very fast processing time
— greater accuracy
— automatic comparison against age matched norms
— automatic colour axis determination
— comparison of results from serial tests
— runs on readily available micro-computers

We have found it invaluable in our daily clinical practice.

The program listing from page 156 to 159 contains an abridged version of the program. It is fully functional, but obviously lacks the whistles and bells of the full program which is too long for publication in this journal. The full program can be obtained from the author on request.

FUTURE DEVELOPMENTS

We are presently working on a totally computerised anomaloscope which will enable quick accurate testing of colour vision without the need to purchase a separate anomaloscope. This should provide anyone with access to an IBM microcomputer (with a VGA monitor) with an immediately useful clinical tool for everyday use.

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```pascal
program Farnsworth;
{Farnworth.Munsell 100 Hue scoring and graphing}
{Short Version 7}
{Copyright 1990, Dr Vivian Balakrishnan, NUH, Singapore}

uses Crt,Dos,Graph;
type
  info = record
                   age : integer; which_eye : char; c : array[1..84] of integer;
          end;
  Int84arraytype = array[1..84] of integer;

var
   c,CapScore : Int84arraytype;
   {Raw cap arrangement,ie,.c[1] is the numerical label of
     the 1st cap , c[84] is numerical label of the last cap }
   Total_Error_Score,BY_Score,RG_Score : integer;
   n,BoxNo : shortint; ch,pr : char; testdata : info;

procedure initial_assignment;
begin
        testdata.age := 30; testdata.which_eye := ' ';
        for n := 1 to 84 do c[n] := n;
end;

procedure display_caps;
var n : byte;
begin
   clrscr;
   for  n := 1 to 84 do
     begin
        GotoXY((((n-1) mod 21)+1)*3 , ((((n-1) div 21)+1)*3)); write(c[n]);
     end;
end;

procedure getinput;
   var pos,EmptyCapPos,n : byte; displaced_cap,inputinteger,Code : integer;
        inputstring : string[2];
   begin
      pos := 1; displaced_cap := 0;
     repeat
      GotoXY((((pos-1) mod 21)+1)*3 , ((((pos-1) div 21)+1)*3));
      TextAttr := 16; write(c[pos]); NormVideo; ch := readkey;
      if ch = #0 then  ch := readkey;
      case ch of
        #77 : inc(pos,1); #75 : dec(pos,1); #80 : inc(pos,21); #72 : dec(pos,21);
      {numerical key}
        '0'..'9' : begin
                      inputstring[1] := ch;
                      repeat ch := readkey; until (ch >= '0') and (ch<='9');
                      inputstring[2] := ch; inputstring[0] := #2;
                      val(inputstring,inputinteger,Code); n := 1;
                      while c[n] <> inputinteger do inc(n); EmptyCapPos := n;
                      if pos > EmptyCapPos then
                              for n := EmptyCapPos to (pos-1) do c[n] := c[n+1]
                         else
                              for n := EmptyCapPos downto (pos+1) do c[n] := c[n-1];
                      c[pos] := inputinteger;
                    end;
      end;{case}
      if pos < 1 then pos := 1; if pos > 84 then pos := 84; display_caps;
     until (ch = #13) and (displaced_cap = 0) {or (x < 3) or (x > 66)or (y < 3) or (y > 12)};
   end;

 procedure CalculateScores ;
  var n : byte;
  begin
      Total_Error_Score := 0; BY_Score := 0; RG_Score := 0;
      for n := 1 to 84 do
        begin
            case n of
              {adjacent to left anchor cap}
              1,22,43,64 : CapScore[c[n]] := Abs(c[n]-(n-1))+ Abs(c[n]-c[n+1]);
              {adjacent to right anchor cap}
              21,42,63,84 : CapScore[c[n]]:= Abs(c[n]-(n+1))+ Abs(c[n]-c[n-1]);
              else
                 CapScore[c[n]] := Abs(c[n]-c[n-1]) + Abs(c[n]-c[n+1]);
```

```pascal
                end;{case}
                Total_Error_Score := Total_Error_Score + CapScore[c[n]] - 2;
                case c[n] of
                    1..12,34..54,76..84 : BY_Score := CapScore[c[n]] - 2 + BY_Score;
                    13..33,55..75 : RG_Score := CapScore[c[n]] -2 + RG_Score;
                end;{case}
        end;
  end;

function critical_score(age_of_testee:integer ; which_eye:char):real;
  type scoretype = array[1..14] of real;
  const
    age : scoretype = (12,16,20,25,30,35,40,45,50,55,60,65,70,75);
    monoscore: scoretype = (193,135,110,104,110,124,142,164,189,213,234,256,281,317);
    binoscore: scoretype = (154,114,93,89,106,123,137,151,161,172,178,188,200,216);
  var
    score : scoretype; n : integer;
  begin
    case which_eye of
    'B','b' : score := binoscore;    else
      score := monoscore;
    end;
    case age_of_testee of
       0..12: critical_score := score[1];
       75..200: critical_score := score[14];
    else
      n := 1;
      while age_of_testee >= age[n] do inc(n);
               c r i t i c a l _ s c o r e   : =   s c o r e [ n - 1 ]
+((score[n]-score[n-1])/(age[n]-age[n-1]))*(age_of_testee-age[n-1]);
    end; {case}
  end;

procedure InterEyeComparison;
  var score1,score2,c : real;
  begin
    ClrScr; Write('What is the total error score of the first eye ?  ');
    Readln(score1);
    Write('What is the total error score of the second eye ? '); Readln(score2);
    GotoXY(10,12); C := Abs( (Sqrt(score1)-0.25)-Sqrt(score2)  );
    if C > 2.39 then
      begin
        Write('Difference between eyes is significant (p < 0.05)');
      end
    else Write('Difference between eyes in not significant (p > 0.05)');
    Readln;
  end;

function IntToStr(i:integer):string;
  var s : string[3];
  begin
    Str(i:3,s); IntToStr := s;
  end;

procedure DisplayResults;
var
  CapArrangement,RowScore : array[1..4] of string[63];
  n,m : byte; f : text;
begin
  assignCrt(f); Rewrite(f); ClrScr;

  writeln(f,'Age : ',testdata.age);
  writeln(f,testdata.which_eye,' eye'); writeln(f);
  Writeln(f,'Total Error Score is  ',(Total_Error_Score));
  Writeln(f,'Partial Blue-Yellow error score is ',BY_Score);
  Writeln(f,'Partial Red-Green error score is    ',RG_Score);
  if Total_Error_Score > Critical_Score(testdata.age,testdata.which_eye) then
    writeln(f,'Abnormal result - p < 0.05')
  else
    writeln(f,'Within normal limits - p > 0.05');
  case testdata.which_eye of
    'B','b': write(f,'Critical score for binocular ');
  else
    write(f,'Critical score for monocular ');
  end;
  Write(f,'test for subject aged ',testdata.age,' is ');
  Writeln(f,Critical_Score(testdata.age,testdata.which_eye):3:1);
```

```pascal
end;

procedure StartUpGraphics;
  var Gd,Gm :integer;
  begin Gd := Detect; InitGraph(Gd,Gm,''); end;

procedure PlotGraph(Radius : Int84arraytype ; Xasp,Yasp : word);
  var  m,n,FirstX,FirstY,PriorX,PriorY,CircleBaseRadius,CircleRadiusStep : integer;
       p : word; ArcCoords : ArcCoordsType; st : string[2];
  begin
    SetAspectRatio(Xasp,Yasp); CircleBaseRadius := 10; CircleRadiusStep := 10;
    SetTextJustify(CenterText,CenterText); SetTextStyle(SmallFont,HorizDir,2);
    OutTextXY(75,(GetMaxY-5),'Copyright 1990, Vivian Balakrishnan');
    for m := 1 to 10 do
      for n := 1 to 42 do
        begin
          p := round(((n-1)*360*2/84)+90);
                 Arc(((GetMaxX+1)   div   2),((GetMaxY+1)   div
2),p,p+1,((m*2))*CircleRadiusStep+CircleBaseRadius);
              if m = 10 then
                begin
                  Str((n*2)-1,st); GetArcCoords(ArcCoords);
                  SetTextStyle(SmallFont,HorizDir,6);
                  OutTextXY(ArcCoords.Xstart,ArcCoords.Ystart,st);
                end
              else
                if (n = 1) or (n = 22) then
                  begin
                    Str(m*2,st); GetArcCoords(ArcCoords);
                    SetTextStyle(SmallFont,HorizDir,4);
                    OutTextXY(ArcCoords.Xstart,ArcCoords.Ystart,st);
                  end;
            end;

    for m := 1 to 84 do
      begin
        p := round(((m-1)*360/84)+90);
               Arc(((GetMaxX+1)   div   2),((GetMaxY+1)   div
2),p,p+1,Radius[m]*CircleRadiusStep+CircleBaseRadius);
        GetArcCoords(ArcCoords);
        with ArcCoords do
        begin
          case m of
            1 : begin FirstX := Xstart; FirstY := Ystart; end;
            84: begin
                   Line(Xstart,Ystart,PriorX,PriorY); Line(Xend,Yend,FirstX,FirstY);
                end;
          else Line(Xstart,Ystart,PriorX,PriorY);
          end;(case)
          PriorX := Xend; PriorY := Yend;
        end; (with ArcCoords)
      end; (for m := 1 to 84)
  end;

procedure GetBioData;
  var
    age : string[3]; which_eye_str : string[1]; which_eye : char; Code : integer;
  begin
    writeln;
    write('Age of patient                    '+IntToStr(testdata.age));
    GotoXY(36,WhereY);readln(age);
    age := age + copy(IntToStr(testdata.age),length(age)+2,2);
    val(age,testdata.age,Code);
    write('Which eye is being tested         '+testdata.which_eye);
    GotoXY(35,WhereY);readln(which_eye_str);
    if byte(which_eye_str[0]) = 1 then testdata.which_eye := char(which_eye_str[1]);
  end;

begin
  repeat
    TextMode(LastMode); Clrscr; GotoXY(10,3);
    Write('          Farnworth-Munsell 100 Hue Test Analyser');
    GotoXY(10,10);            Write('1    Run a new test');
    GotoXY(10,14);            Write('3    Inter-eye comparison');
    GotoXY(10,18);            Write('5    Quit');
    GotoXY(10,20);            Write('Please type the number of the your choice  ');
    Readln(ch); Clrscr;
```

```
      case ch of
            :begin
                initial_assignment; GetBioData; display_caps; getinput;
                CalculateScores; DisplayResults; readln;
                StartUpGraphics; PlotGraph(CapScore,1,1);
                SetTextStyle(TriplexFont,HorizDir,2);
                readln; RestoreCRTMode; CloseGraph;
            end;
      '3':InterEyeComparison;
      end;{case}
   until ch = '5';
end.
```

REACHING NEW HEIGHTS
IN CUSTOMER SATISFACTION

It is 8.30am, Monday morning in Johnson & Johnson's office. Everyone is in the conference room. In today's monthly meeting, a number of important issues are discussed. Almost all issues discussed are related to customer satisfaction. "How can we serve our customers better?" "Should we try this way from now on?" At Johnson & Johnson, everyone is talking about our most important mission – TOTAL CUSTOMER SATISFACTION.
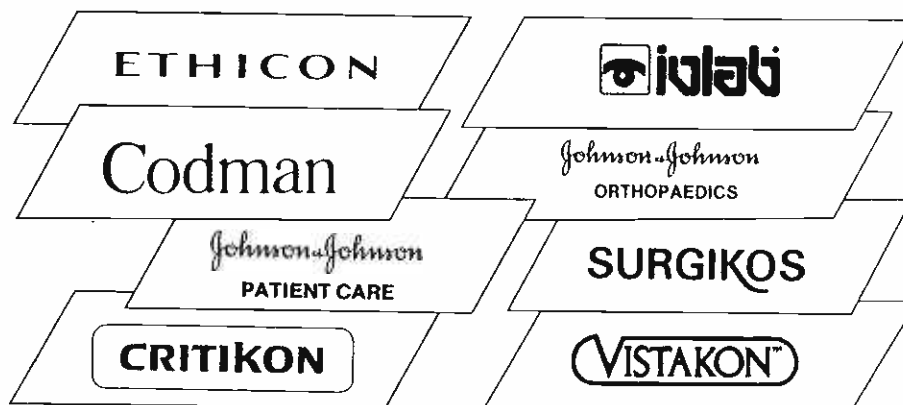
At 11.45am, Caroline and Susan went out to lunch. A little too early? No, we have implemented a flexible lunch schedule so that we have full telephone coverage throughout lunch for customer service function. At 12.30, it was Selvi and Elicia's turn for lunch. This is just one example of how Johnson & Johnson is introducing new policies to serve its customers better.

In 1990, we conducted a nation wide customer satisfaction survey. We asked you what you value most in terms of services offered by suppliers and qualities of sales representatives. We, then, asked you how we are doing against other suppliers on these attributes. Based on your valuable inputs, we have now identified what services you require of us. You told us we were doing better than other suppliers on most attributes. Although we were happy with your performance rating on Johnson & Johnson, we do not want to be complacent.

Reaching New Heights is our theme for 1991. From top management down the line, we have committed ourselves to strive for TOTAL CUSTOMER SATISFACTION. Based on the 1990 survey results, we have set goals and plans to improve our customer satisfaction level. Our ultimate goal is improved health care for Singapore through providing the highest quality products and services to our valued customers.