



**Determining eye-hand co-ordination using the sport vision trainer (SVT™): an evaluation of test-retest reliability**

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3 1 Determining eye-hand co-ordination using the sport vision trainer (SVT™): an  
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6 evaluation of test-retest reliability

7 3 Abstract

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9 4 *Objectives:* The purpose of this investigation was to assess the number of test-retest  
10 5 trials required to familiarise participants in order to provide acceptable reliability for  
11 6 the measurement of an eye-hand co-ordination task using the Sport Vision Trainer  
12 7 (SVT™). *Design:* Two schedules were conducted (S1 and S2); *Methods:* (S1): Sixty-  
13 8 four participants (male n=51, age 20.8±4.9 years; female n=13, age 20.1±2.1years)  
14 9 attended four sessions each one week apart, and undertook four trials using the  
15 10 SVT™. (S2): Sixty participants (male n=46, age 20.8±4.9 years; female n=14, age  
16 11 20.1±2.1 years) attended one 20-minute schedule consisting of four consecutive  
17 12 trials using the SVT™. *Results:* Limits of agreement (LoA) analyses showed that  
18 13 absolute reliability was increased in both studies. The LoA for S2 indicate that error  
19 14 decreased between trial 1-2, 2-3, and 3-4; ±0.95 (CI,-1.16,+2.56sec), ±0.97 (CI,-  
20 15 1.66,+2.14sec), ±0.69 (CI,-1.08,+1.62sec). *Conclusion:* Reliable measurements of  
21 16 eye-hand co-ordination can be obtained using the SVT™ in one session.

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19 Keywords: Psychomotor Performance; Visual Motor Co-ordination; Reliability of  
20 Results; Reaction Time; Test-Retest Reliability

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3 22 Introduction  
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5 23 The visual system plays a critical role in sports performance (Williams, Davids, &  
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7 24 Williams, 2005), as it does in the performance of virtually all perceptual-motor skills  
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9 25 (Paillard, 1990). To advance sports performance through improving vision an  
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11 26 understanding of the visual demands of different sports is required. Evaluation of the  
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13 27 degree that varying visual parameters can be adapted through the training of visual  
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15 28 abilities also needs to be considered. Eye-hand co-ordination is a crucial aspect of  
16  
17 29 sport performance as decisions frequently need to be made very quickly based on  
18  
19 30 the presentation of a wide range of visual stimuli. Eye-hand co-ordination also plays  
20  
21 31 an integral role in sports vision and has been researched in many sport contexts  
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23 32 such as goalkeeping in soccer (Nagano, Kato, & Fukuda, 2004), defence in  
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25 33 basketball (Laurent, Ward, Williams, & Ripoll, 2006), and general passing, and  
26  
27 34 throwing and hitting in other sports (Zupan, Arata, Wile, & Parker, 2011). Despite this  
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29 35 there are currently no recognised standardised measurements for testing eye-hand  
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31 36 co-ordination in sport. Traditionally researchers have used non-validated tools, or  
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33 37 ones with little established accuracy (Du Toit et al., 2011). The development of a  
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35 38 reliable measurement tool would therefore provide athletes and coaches with an  
36  
37 39 effective evaluation device for improving sport performance. The Sport Vision Trainer  
38  
39 40 (SVT™) has the potential to be such a device. The SVT™ 32 sensor pad is  
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41 41 a portable system developed for teams/practitioners who want to use the SVT™  
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43 42 in different locations. It can also be used either in landscape or portrait positions to  
44  
45 43 portray both the proactive and reactive eye-hand co-ordination demands of many  
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47 44 sports.  
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49 45 Practically, some amount of biological error is always present with continuous  
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51 46 measurements (Hopkins, 2000). Therefore reliability could be considered as the  
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3 47 amount of measurement error that has been deemed satisfactory for the successful  
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5 48 practical use of a measurement device. The publication of data for reliability studies  
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7 49 has been acknowledged to considerably enhance comparisons of the consistency of  
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9 50 testing and equipment (Hopkins, 2000). Consequently practitioners can be assured  
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11 51 that any improvement in performance is due to interventions introduced and eliminate  
12  
13 52 potential differences in gender, experience, and any familiarisation effect of the  
14  
15 53 SVT™ as a factor. Currently there are no studies that assess the test-retest reliability  
16  
17 54 of the SVT™. Therefore, the purpose of this investigation was to assess the **number**  
18  
19 55 **of test-retest trials required using the SVT™ to familiarise participants in order to**  
20  
21 56 **provide acceptable reliability for the measurement of an eye-hand co-ordination task.**  
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23 57 The second purpose of this investigation was to determine **if a shorter schedule of**  
24  
25 58 **familiarisation could be used to assist the researcher in a more appropriate, timely**  
26  
27 59 **collection period.**

## 31 Methods

### 34 Research Design

36 62 Prior to testing all procedures were described and a full demonstration was given to  
37  
38 63 the participants in order to give them an idea of the testing protocol without them  
39  
40 64 actually using the SVT™ before any familiarisation session taking place. Two  
41  
42 65 schedules were then carried out. **The same investigator was responsible for data**  
43  
44 66 **collection for both schedules. Data were recorded electronically via the SVT™ and**  
45  
46 67 **automatically saved to an excel file.** The first schedule (S1) took place over a four  
47  
48 68 week period based on recommendations to assess reaction times (Ando, Kida, &  
49  
50 69 Oda, 2004). Once this had been completed a second period of data collection was  
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52 70 undertaken (S2) with different participants to assess whether the same trials (T), as  
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3 71 endorsed by the manufacturer of the equipment (Sports Vision, 2012), could be  
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5 72 conducted in a shorter (approx. 20-minutes), and therefore more practical session.  
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7 73 Participants

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9 74 Sixty-four sports participants (male n=51, Female n=13) volunteered for S1 and sixty  
10  
11 75 (male n=46, female n=14) for S2. The participants were of mixed abilities ranging  
12  
13 76 from collegiate to national standard in a variety of team and individual sports.  
14  
15 77 Records of the experience (S1, 6.03±4.19yrs; S2, 6.21±3.73yrs) and hours of training  
16  
17 78 per week (S1, 5.34±3.52hrs; S2, 5.88±4.27hrs) in the participants sport was  
18  
19 79 obtained. Vision health questionnaires (Williams et al., 2005) were also completed to  
20  
21 80 assess suitability for the study. Anyone who had suspected visual  
22  
23 81 impairment/difficulties was referred to an optometrist. Participants exhibiting any  
24  
25 82 visual deficiencies were excluded from participating and referred to an optician. Four  
26  
27 83 participants (n=2 from S1, and n=2 from S2) were excluded from the final  
28  
29 84 calculations. Any participant suffering shoulder, wrist or finger injury during the last  
30  
31 85 six months was excluded. All included participants reported normal visual acuity  
32  
33 86 either unaided or while wearing their own corrective lenses. All experimental  
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35 87 procedures were approved by the Institutional Ethics committee prior to testing. All  
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37 88 participants were informed of the risks and procedures of the investigation prior to  
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39 89 giving written informed consent.  
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45 90 Testing Procedures

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47 91 In S1 participants subsequently completed four sessions of six trials using the SVT™  
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49 92 32 sensor pad. This test is carried out on a display board (135 cm in length, 18 cm in  
50  
51 93 width, and 60cms in height) with 32 touch-sensitive red light emitting diodes (LED's).  
52  
53 94 All trials took place at the same time of day to avoid any effects of circadian  
54  
55 95 variations (Atkinson & Reilly, 1996; Edwards, Waterhouse, & Reilly, 2008). Each  
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3 96 session was separated by one week as reliability of cognitive variables have been  
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5 97 shown to be highly reliably over a 4-week period (Wallman, Morton, Goodman, &  
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7 98 Grove, 2005). The ambient light in the room was carefully controlled and set at 420  
8  
9 99 Lux (Sport Vision, 2012) using a Lux light meter (CEM DT-1300, Shenzhen, China).  
10  
11 100 The SVT™ was programmed to use a proactive mode (Sport Vision, 2012) which  
12  
13 101 meant that lights stayed illuminated until the participant responds by hitting them.  
14  
15 102 Participants were required to touch each light as quickly as possible. The SVT™  
16  
17 103 programme waits until it has measured the response before switching on the next  
18  
19 104 light. Participants stood directly in front of a panel of 32 lights which displayed a  
20  
21 105 centrally programmed sequence of 20 lights (the centre 16 lights, 4 by 4 array) which  
22  
23 106 randomly illuminated. The height of the top of the SVT™ from the floor was  
24  
25 107 standardised at 1.77cm for men and 164.4cm for females (NHS, 2012) and was  
26  
27 108 positioned in a landscape format. Time to hit the sequence of 20 lights was recorded  
28  
29 109 in milliseconds. The SVT™ program randomised the target order and location for  
30  
31 110 every trial to ensure fair test comparisons between users. The first two trials of 20  
32  
33 111 lights were practice runs and means of the last four measurement trials were  
34  
35 112 displayed at the end of the each trial. In S2 the same protocol was adhered to,  
36  
37 113 except the **six** trials were carried out with 10 second breaks, consecutively in one  
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39 114 session lasting approximately 20-minutes.  
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#### 45 Statistical Analysis

46  
47 116 For both S1 and S2 comparisons were conducted on the dependent variable of mean  
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49 117 task completion time over the last four trials, in seconds, for Session 1 versus  
50  
51 118 Session 2, Session 2 versus Session 3, and Session 3 versus Session 4, using the  
52  
53 119 software for the Hopkins reliability spread sheet (Hopkins, 2012). This generated  
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55 120 **coefficients of variation (CV), intra-class correlation coefficients (ICC), Pearson**  
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3 121 correlation coefficients (r), and standard errors of measurements (SEM) for each  
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5 122 comparison as recommended for these types of investigations (Atkinson & Nevill,  
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7 123 1998; Hopkins, 2000; Morrow & Jackson, 1993) (Table 2). To derive the within-  
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9 124 subject variation expressed as a coefficient of variation (CV) all data was log-  
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11 125 transformed in accordance with the methodology identified in Hopkins reliability  
12  
13 126 spreadsheet (Hopkins, 2012), differences between trials were then calculated for  
14  
15 127 each participant. Acceptable reliability was identified as being a CV <5% (Vincent  
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17 128 2005) and ICC's >r=0.80, below which reliability has been suggested to be  
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19 129 "questionable" (Atkinson and Nevill 1998). With three comparisons within each  
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21 130 schedule, probability values for Pearson coefficients were evaluated against a  
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23 131 Bonferroni adjusted alpha level of  $P \leq .017$ . Bland-Altman plots (Bland & Altman,  
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25 132 1986) were used to describe the Limits of agreement (LoA) for each comparison  
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27 133 within each schedule, following the method described by Atkinson and Nevill (1998).  
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29 134 This generates 95% confidence intervals for differences in the performance of  
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31 135 individuals across sessions in each comparison. Differences falling outside these  
32  
33 136 confidence intervals may be regarded as random. A Kolmogorov-Smirnov test was  
34  
35 137 conducted to test normality of data. Mann-Whitney's (Nachar, 2008) U test was  
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37 138 conducted to evaluate the differences in performance between S1 and S2.  
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39 139 Potential gender differences in performance were tested within each schedule,  
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41 140 respectively, using a mixed between-within participants ANOVA, with gender as a  
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43 141 between-participants independent variable and mean task completion times for  
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45 142 Sessions 1 to 4 as a within-participants independent variable at four levels. Finally,  
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47 143 the mean difference in participants' task completion times across all four trials was  
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49 144 tested using schedule as a between-participants independent variable in a t-test. The  
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51 145 suitability of these means for parametric analysis was established by graphical  
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3 146 examination of their distribution and by statistical analysis of their skewness and  
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5 147 kurtosis, as described by Tabachnick and Fidell (2001). There was no evidence to  
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7 148 suggest that heteroscedasticity was present. All values presented are displayed as  
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9 149 mean±standard deviation (SD), and a level of  $p < 0.05$  was used to define statistical  
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11 150 significance. All statistical procedures were conducted using SPSS17 statistical  
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13 151 software (IBM, Chicago, USA).

## 152 Results

153 Acceptable reliability was observed following the completion of four trials in both  
154 schedules. All trials demonstrated a reduction in the CV, SEM and ICC across the  
155 trial comparisons from T1-2 to T3-4 (Table 1 and Table 2 for mean performance  
156 times and reliability measurements, respectively). Pearson's  $r$  revealed no significant  
157 relationship between experience and difference in means between T1 and T4 for  
158 both studies: S1,  $r(64) = 0.128$ ,  $P = 0.352$ ; S2,  $r(60) = -0.103$ ,  $P = 0.432$ . Pearson's  
159 correlation revealed no significant relationship between training hours per week and  
160 difference in means between T1 and T4 for both studies: S1,  $r = -0.106$ ,  $P = 0.452$ ; S2,  
161  $r = -0.011$ ,  $P = 0.931$ . There was no significant differences in participants' task  
162 completion times across all four sessions:  $t(122) = 1.906$ ,  $P = 0.059$ , two-tailed. There  
163 was no significant effect of groups between test schedules (The mean ranks of S1  
164 and S2 were 68.11 and 156.52, respectively;  $n = 64$ ,  $n = 60$ ,  $U = 1561$ ,  $p < 0.072$ , two  
165 tailed). A significant main effect for gender was observed for the mean task  
166 completion times between trial 1-4 in S1:  $F_{(1,62)} = 4.828$ ,  $P = 0.03$ ,  $\eta^2 = 0.07$ ,  $CI = 10.52$ -  
167 11.33, and no significant main effect for gender for the mean task completion times  
168 between trial 1-4 in S2:  $F_{(1,58)} = 2.079$ ,  $P = 0.16$ ,  $CI = 10.39$ -11.26. In S1 a significant  
169 main effect was observed for trial (Greenhouse-Geisser adjustments utilised):  
170  $F_{(2.596, 160.958)} = 29.574$ ,  $P = 0.001$ ,  $\eta^2 = 0.323$  (Table 2). In S2 a significant main effect



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3 171 was observed for trial (Greenhouse-Geisser adjustments utilised):  
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5 172  $F_{(2.52, 146.163)}=21.987$ ,  $P=0.001$  (Table 2).  
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173  
174 The LoA analysis (Figure 1) shows that absolute reliability is increased from T1-T2 to  
175 T3-T4 in both studies. Improved LoA was observed between the four trials (trial 1-2,  
176 trial 2-3, and trial 3-4) for S1:  $\pm 1.11$  (CI, -1.37, +2.99 sec),  $\pm 1.07$  (CI, -1.76, +2.44  
177 sec),  $\pm 0.74$  (CI, -1.04, +1.86 sec), and S2:  $\pm 0.97$  (CI, -1.16, +2.56 sec),  $\pm 0.95$  (CI, -  
178 1.66, +2.14 sec),  $\pm 0.69$  (CI, -1.08, +1.62 sec) respectively. Pearson's r value also  
179 indicated an increasingly strong relationship from trial 2-1 to trial 4-3 in both  
180 schedules (Table 2).

181 Discussion

182 The purpose of this investigation was to assess the number of test-retest trials  
183 required to familiarise participants in order to provide acceptable reliability for the  
184 measurement of an eye-hand co-ordination task using the Sport Vision Trainer  
185 (SVT™). Furthermore a second testing protocol was conducted in order to  
186 determine if a more logistically practical schedule of familiarisation could be achieved  
187 with the same number of test-retest trials. As far as can be ascertained, there is no  
188 current research evaluating the SVT™, or using it as a research tool, despite existing  
189 evidence of effects of influences of familiarisation (Duncan, Al-Nakeeb & Nevill,  
190 2005). The design and analysis of this study factored in a random participants  
191 sample identified using recommended methods for assessing reliability in sports  
192 medicine based research (Atkinson & Nevill, 2001). In turn this enabled a precise  
193 estimate of measurement error parameters (CV; ICC and SEM) which was used to  
194 determine whether the SVT™ was acceptable for use in the simplest experimental  
195 setting (i.e. same experimenter and identical equipment). Random error was shown

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3 196 to reduce in all measurement error parameters as more tests were administered, until  
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5 197 acceptable reliability was deemed satisfactory using ICC. These were interpreted as  
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7 198 0.70-0.80 acceptable, 0.80-0.89 strong and 0.90-1.0 high correlation (Vincent, 2005).  
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9 199 S1 identified an ICC of 0.87 (T3-4) and S2 0.89 (T3-4) respectively. Although the  
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11 200 present study showed a significant difference in results between gender in S1, the  
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13 201 effect size was small, and should be viewed with caution. There was no significance  
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15 202 displayed for gender in S2 supporting previous research on eye-hand visual reaction  
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17 203 times (Akarsu, Çaliskan, & Dane, 2009; Dane & Erzurumluoğlu, 2003) using a  
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19 204 software package of random stimulus presentation. Applying the protocol outlined in  
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21 205 S1 would take 4 weeks to complete; we therefore shortened the protocol (S2) into  
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23 206 one testing session to see if **acceptable** reliability could be achieved in a more  
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25 207 optimally practical testing duration. **The results for S2 showed similar values to S1**  
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27 208 **allowing testing to take place in a shorter timeframe.** CV's of 4.94% and 4.76% for  
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29 209 trials 3-4 in both S1 and S2 respectively identified (Vincent, 2005) (<5%) findings as  
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31 210 an acceptable figure for reliability.  
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36 211 As previous measures of **eye-hand** co-ordination and reaction in a sporting context  
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38 212 have generally used non-validated tools, the development of a reliable training aid is  
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40 213 highly relevant. Consequently this may provide athletes and practitioners with an  
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42 214 effective tool for improving sports performance through increasing eye-hand co-  
43  
44 215 ordination. The results also showed no significant relationships between experience,  
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46 216 training hours and abilities offering the prospect of using the SVT™ for different  
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48 217 populations using this familiarisation strategy. For example, although the present  
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50 218 study focused on its use from a sporting perspective, these findings may present  
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52 219 opportunities to use the SVT™ in improving **eye-hand co-ordination in general**  
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54 220 **training** and other specialised instances (e.g. rehabilitation of motor dysfunction,  
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3 221 visual deficiencies injury rehabilitation process, alternative to physical activities  
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5 222 during recovery). Minimal measurement error during the collection of interval-and-  
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7 223 ratio-type data has been identified as critically important for the assessment of  
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9 224 performance (Atkinson & Nevill, 1998). Practically, as some amount of biological error  
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11 225 is always present with continuous measurements, reliability in this study was  
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13 226 considered as the amount of measurement error that has been deemed satisfactory  
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15  
16 227 for the successful practical use of the SVT™.

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18 228 The findings also suggest that using the shorter **schedule** outlined in S2 may allow  
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20 229 future researchers to minimise familiarisation testing time and to condense a  
21  
22 230 potentially time constraining activity to less than 20-minutes. The data is reflective  
23  
24 231 and of the same magnitude as would typically be expected for the current population  
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26 232 (Chang, Labban, Gapin, & Etnier, 2012). In order for future research on the validity of  
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28 233 the SVT™ to be carried out it is important that the values indicated from repeated  
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30 234 measurements are sufficiently meaningful. The 95% confidence intervals indicate  
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32 235 that in all instances the change in CV is likely to be real for both **schedules** tested in  
33  
34 236 the present study. **Future research should be conducted to determine whether skills**  
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36 237 **learned on the SVT™ can be transferred into other contexts (e.g., improved sport**  
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38 238 **performance, functional movements, rehabilitation outcomes). The SVT™ lends itself**  
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40 239 **to the investigation of various elements impacting upon eye-hand co-ordination (e.g.:**  
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42 240 **nutritional interventions, fatigue, environmental conditions, stimulus characteristics).**  
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44 241 **Of particular interest is how different training approaches may impact upon the**  
45  
46 242 **effective development of eye-hand co-ordination as measured using the SVT™ (e.g.,**  
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48 243 **instructional approaches, practice schedules, implicit and explicit learning, and**  
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50 244 **performance under pressure). Such studies using the SVT™ may provide athletes**  
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52 245 and practitioners with an effective tool for improving sports performance. **A key**

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3 246 limitation of the present study is the use of a relatively typical sample of healthy  
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5 247 young adults, and as such the data presented here may not transfer to other  
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7 248 populations (e.g., individuals with cognitive and physical impairments). Therefore,  
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9 249 future research using the SVT™ as a measure of eye-hand co-ordination in such  
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11 250 populations should consider the assessment of effective familiarisation strategies.

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14 251 When investigating healthy populations, it is recommended that practitioners using  
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16 252 the SVT™ should include the protocol (S2) described in the present paper to inform  
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18 253 future interventions to eliminate any residual learning effects.

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21 254 Conclusion

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23 255 To our knowledge this is the first study to identify and analyse the reliability of test-  
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25 256 retest familiarisation trials for the SVT™. In summary the findings of the study  
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27 257 indicate that the familiarisation trials were statistically reliable over a four week  
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29 258 period, and in a shorter 20-minute consecutive session. The shorter familiarisation  
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31 259 protocol ensures that the logistics of testing are simplified for practitioners whilst also  
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33 260 providing acceptable test-retest reliability. These results suggest that researchers  
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35 261 may use the SVT™ for a range of potential training approaches and intervention  
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37 262 studies. In order for future research on the validity of the SVT™ to be carried out it is  
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39 263 important that the values indicated from repeated measurements are sufficiently  
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41 264 meaningful. It can therefore be concluded that reliable measurements of eye-hand  
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43 265 co-ordination can be obtained in one short session using the SVT™, providing four  
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45 266 familiarisation sessions of six trials have taken place following description and a full  
46  
47 267 demonstration of the procedure.

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Tables

**Table 1.** Descriptive statistics of mean performance times achieved in each Schedule (mean ± SD)

Participants	Age (yrs)	T1		T2		T3		T4	
		Mean* (s)	Threshold*(s)	Mean(s)	Threshold(s)	Mean(s)	Threshold(s)	Mean(s)	Threshold(s)
M (n=51)	20.8±4.9	11.39±1.57	0.56±0.07	10.53±1.55	0.52±0.07	10.2±1.35	0.51±0.68	9.80±1.15	0.48±0.05
<b>S1</b> F (n=13)	20.1±2.1	12.08±1.50	0.60±0.07	11.53±1.80	0.57±0.88	11.15±1.52	0.55±0.07	10.72±1.39	0.53±0.06
Total (n=64)	20.4±4.4	11.53±1.57	0.57±0.07	10.74±1.64	0.53±0.08	10.39±1.42	0.52±0.07	9.99±1.24	0.50±0.06
M (n=46)	20.8±4.9	11.25±1.7	0.56±0.08	10.53±1.74	0.52±0.08	10.29±1.51	0.51±0.07	9.98±1.40	0.49±0.07
<b>S2</b> F (n=14)	20.1±2.1	11.76±1.05	0.58±0.05	11.12±1.18	0.55±0.05	10.92±1.37	0.54±0.06	10.75±1.48	0.53±0.07
Total (n=60)	20.85±4.3	11.37±1.58	0.56±0.07	10.67±1.64	0.53±0.08	10.43±1.50	0.52±0.07	10.16±1.44	0.50±0.07

+ Mean (±) SD proactive time to hit twenty light sequences

\*Threshold: Mean proactive reaction time for 20 lights

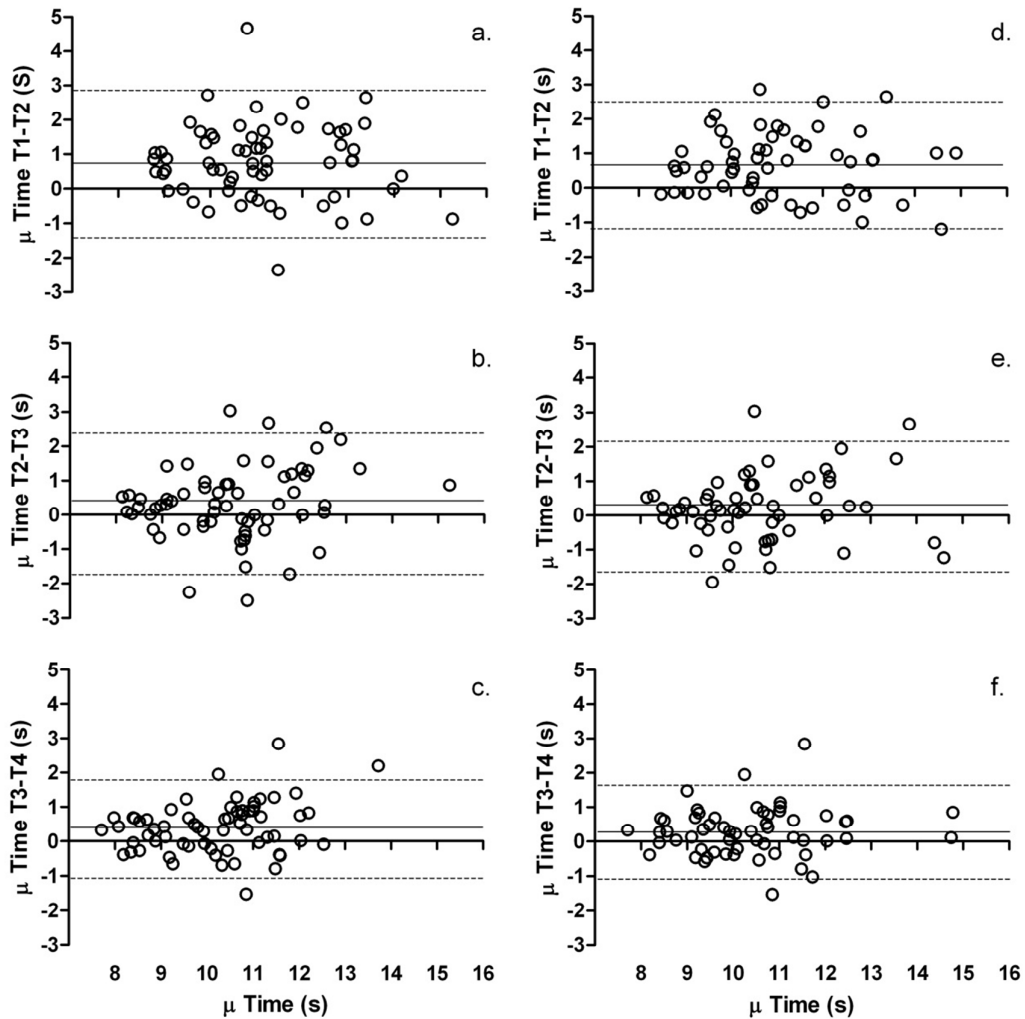
S=Schedule, T=Trial

**Table 2.** Reliability (Coefficient of variation, CV), Intraclass correlation coefficient (ICC), Pearson's r, Standard error measurement (SEM) and Bonferroni post hoc comparisons between trials.

S1						S2				
TRIALS	*Typical Error CV	ICC	Pearson's r	Bonferroni Adjustment	SEM	*Typical Error CV	ICC	Pearson's r	Bonferroni Adjustment	SEM
1-2	7.30	0.74	0.76	P=0.001	9.1	6.21	0.74	0.82	P=0.001	7.8
2-3	7.14	0.75	0.77	P=0.255	7.4	6.43	0.80	0.83	P=0.803	6.6
3-4	4.94	0.86	0.87	P=0.004	5.7	4.76	0.81	0.89	P=0.019	5.1

\*95% confidence interval) for all trials

## Figure Legends



**Figure 1:** Bland Altman plots showing differences between tests against each individual mean for Schedule 1; (a) *trial 1-trial 2*, (b) *trial 2-3* and (c) *trial 3-trial 4*, and Schedule 2; (d) *trial 1-trial 2*, (e) *trial 2-3* and (f) *trial 3-trial 4*. Solid lines represent mean bias; dashed lines represent 95% limits of agreement.