International Journal of Sports Science & Coaching

Further evidence against eye-hand coordination as a general ability

Journal:	*International Journal of Sports Science & Coaching*
Manuscript ID	SPO-17-0174.R2
Manuscript Type:	Research Note
Date Submitted by the Author:	06-Nov-2017

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Abstract:	A number of companies are marketing general eye hand coordination (EHC) training devices, which are purported to enhance performance on the device and in a sporting domain. An act comprising EHC involves the complex combination of a number of distinct functions and an investigation of what tasks share this common factor has not been completed. There is also a lack of evidence investigating the interrelationship between different tests to assess EHC using these devices. A number of different EHC abilities, rather than one common factor, could potentially underpin any range of tasks involving EHC and visual stimuli. Therefore, the present study investigated the theoretical assumption upon which such EHC training devices are based; that is, whether EHC is a general ability. Eighty-seven currently active sportspeople (age 18.6±0.9 years; 58 males and 29 females) completed four tests of EHC: three laboratory tasks (the Sports Vision TrainerTM; Batak ProTM; and Graded Pegboard) and a field task (wall catch test). Intercorrelations between the tasks ranged from weak to strong, but the percentage of shared variance was typically low. Overall, the results do not support the existence of a common EHC ability underpinning performance on general EHC training devices. Consequently, coaches and sport scientists should be aware that training on general EHC training devices is unlikely to transfer to sporting performances. Instead, practitioners are encouraged to explore sport-specific assessment and training of EHC.

Further evidence against eye-hand coordination as a general ability

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Abstract

A number of companies are marketing general eye hand coordination (EHC) training devices, which are purported to enhance performance on the device and in a sporting domain. An act comprising EHC involves the complex combination of a number of distinct functions and an investigation of what tasks share this common factor has not been completed. There is also a lack of evidence investigating the interrelationship between different tests to assess EHC using these devices. A number of different EHC abilities, rather than one common factor, could potentially underpin any range of tasks involving EHC and visual stimuli. Therefore, the present study investigated the theoretical assumption upon which such EHC training devices are based; that is, whether EHC is a general ability. Eighty-seven currently active sportspeople (age 18.6±0.9 years; 58 males and 29 females) completed four tests of EHC: three laboratory tasks (the Sports Vision Trainer™; Batak Pro™; and Graded Pegboard) and a field task (wall catch test). Intercorrelations between the tasks ranged from weak to strong, but the percentage of shared variance was typically low. Overall, the results do not support the existence of a common EHC ability underpinning performance on general EHC training devices. Consequently, coaches and sport scientists should be aware that training on general EHC

training devices is unlikely to transfer to sporting performances. Instead, practitioners are encouraged to explore sport-specific assessment and training of EHC.

Keywords: visuo-motor skills; motor ability; skill acquisition; eye-hand coordination

The drive to excel in elite sport has seen teams and organizations exploring novel training practices to gain an advantage over their competitors. Visual training has been one of the most common avenues pursued by teams in order to gain that advantage (1, 2). One of the key visual skills targeted by such programmes is eye-hand coordination (EHC). EHC refers to the synchronization of the movements of the hands to visual stimuli (3), and has long been regarded as a key contributor to success in specific sports such as table tennis (4), and professions such as surgery (5). Stimulated by this popular opinion, a number of companies now market devices which they claim can be used to measure and enhance EHC (e.g., the Sports Vision Trainer™ (SVT™), Sports Vision Pty Ltd, Australia; Dynavision D2™, Dynavision International LLC, USA; Wayne Saccadic Fixator, Wayne Engineering, USA; Batak Pro™, Quotronics Limited, UK).

An inherent assumption of EHC training devices is that a common factor underpins performances both on these devices and in the domain-specific skills (e.g., catching a cricket ball). Within the motor learning literature, such common factors are termed "general motor abilities" (5, 6). One concern with the conceptualization of EHC as a general ability is that a rigorous analysis of what tasks share this common factor has not been completed. Such an analysis is required because any act of EHC involves the complex integration of a number of distinct functions, including visual detection of the target, focusing attention, perceptual identification, planning and programming the initial interceptive movement, potential online control of the steering of the limb towards the target, and the execution of the grasping/striking movement itself (7). Consequently, it is plausible that the wide range of tasks in which the hands are synchronized to visual stimuli are underpinned by a number of different EHC abilities, and not a single common factor.

Such an interpretation is consistent with the dominant theory in relation to the concept of ability: Henry's specificity hypothesis (8). In Henry's theory, abilities are the hypothetical basic unit of individual differences in performance. Abilities are said to be specific in the sense that the performance of any motor skill is based upon a very large number of independent abilities, with each skill drawing upon an almost unique combination of abilities. Researchers have repeatedly supported Henry's prediction when investigating candidate general abilities such as balance or agility (9-16), and recent studies of individual differences continue to support the specificity hypothesis (17, 18). Thus, although intuitively appealing, there are both theoretical and empirical reasons to doubt the existence of a general EHC ability that underpins both laboratory training devices and domain-specific skills.

Despite these theoretical and empirical arguments against the existence of broad general abilities, the popularity of devices for the assessment and training of general EHC appears to be increasing (1, 19). Furthermore, inspection of the research suggests that EHC may be a more promising candidate for a general ability than balance or agility. Although not directly investigating the existence of general EHC ability, a number of studies have compared performers of differing abilities on unpractised tests that involve EHC. For example, a wall catch test was found to discriminate between different levels of performers (20), and has been included as part of a national talent development programme in table tennis (4). Similar findings have been found in baseball (21), where high school players performed more poorly than college and professional players on a computerised test of EHC. Moreover, an EHC assessment amongst Dutch junior table tennis players aged 7–11 years significantly predicted future competition results (22). In both the studies of Faber et al. (20) and Klemish et al. (21), some findings were inconsistent with the existence of a common EHC ability. For example, while participants in the lowest skill group in both studies performed more poorly on all tests of EHC relative to higher-level performers, there were no differences in performance between the intermediate and high skills groups. In addition, within the study by Klemish and colleagues, the predicted differences between pitchers, whose playing position places a low demand on EHC, and hitters, whose playing position places a high demand on EHC, did not materialise (21). However, the comparison of performers of differing skill levels is a weaker test of the existence of a general ability than experimental approaches (e.g. 11), as multiple factors typically contribute to attainment within a specific sport domain (23). Consequently, these studies suggest that while some findings are incongruent with the concept of general EHC ability, sufficient evidence exists to warrant further investigation in general EHC ability.

Comparing EHC performances across skill levels (20, 21) is complicated by limited access to appropriate populations resulting in small sample sizes, and by the inability to control for intervening variables. A more direct assessment of whether an ability is general or specific involves the comparison of performances on a range of tasks which are hypothetically underpinned by the same ability (10, 12, 14). Using this direct approach, early factor analysis studies did identify an "Aiming" factor, analogous to EHC (24, 25). However, an important criticism of this literature is that most of the tasks used in these studies were highly similar paper and pencil measures (e.g., tracing different patterns). Partially addressing this concern, an investigation of a broader range of laboratory EHC tasks found that performance on the Dynavision D2™ shared 31.4% of its variability with a 30 second performance on a dominant hand pursuit rotor task, and 32.5% with a non-dominant hand performance (based on their reported Pearson Product Moment Correlation Coefficients) (19). The variability shared between the Dynavision device and the Minnesota manual dexterity test was 40.9%. Thus, and in support of the findings of Faber and colleagues (22) discussed earlier, these results from Vesia et al. (19) offer preliminary support for the concept of EHC as a general ability. However, replication and extension to include field tests of EHC is essential so that the scientific and applied communities may have confidence in their use of specific pieces of equipment, and their recommendations with respect to best practice (26). As such, this study investigated the interrelationship between different tests on a range of common commercial (SVT™, Batak Pro™), laboratory (Graded Pegboard) and field (wall catch test) assessments of EHC.

Method

Participants

Eighty-seven sports participants (age 18.6±0.9 years; male athletes n=58, female athletes n=29) volunteered for the study and provided written informed consent prior to testing. Participants were recruited by advertisements on the local Virtual Learning Environment. Inclusion criteria were: an age between 18 and 20 years and being an active

108 participant of a sport. Players with injuries were excluded from the study. Full compliance of the Helsinki Convention were adhered to at all times. Participants had 5.7±4.2 year's experience participating in organized sport, and currently trained for an average of 5.5±4.8 hours per week in a variety of team and individual sports. With regard to their primary sport for participation, 72 participants (82.8%) identified a sport involving either a ball or an object requiring similar EHC responses (e.g. shuttlecock, puck), by contrast to sports such as gymnastics or swimming. Football was the most commonly identified sport (34 participants; 39.1% of the total sample). High level engagement in the identified sport was identified in terms of professional status, or representative selection for competitions at county, national or international level. Forty-five participants (51.7%) reported this level of engagement.

Equipment

Sport vision trainer (SVT™)

Participants completed six trials using the wall mounted non-portable SVT™ 80 sensor pad (1.25 m x 1.25 m). A 20 target self-paced protocol was initiated in which targets were lit in a random sequence. The participant was instructed to successfully identify and strike each stimulus before it changed position. Once a target is struck the SVT™ programme immediately lights the next target. Due to the short duration of the task, the first two trials provided familiarisation, and the mean number of successful strikes for the final four trials was used for analysis. The SVT™ has previously demonstrated test-retest reliability of 4.76%, 0.81, and r = 0.89 for typical error CV, intraclass correlation coefficient (ICC) and Pearson's correlation coefficient respectively (27).

Batak Pro™

Participants completed two 60-second trials using the Batak Pro™ board. The board consists of twelve polycarbonate high impact resistant and high intensity LED cluster targets attached to a strong tubular frame (2.08 m (width) x 0.95 m (depth) x 1.95 m (height)). A 60 second self-paced protocol was initiated in which LEDs were lit in a random sequence. The participant was instructed to identify and strike each stimulus before it changed position. Once a target is struck the Batak Pro™ programme immediately lights the next target. Due to the relatively long duration of the task in comparison to the SVT™, the first trial provided familiarisation, and the number of successful strikes on the second trial was used for analysis.

Graded Pegboard

The Sammons Preston® Graded Pegboard Set (Patterson Companies Inc, UK) is a 30-hole pegboard consisting of a 305 mm x 255 mm wooden board and 30 pegs in five colours. Pegs range in height from 3.18 cm to 6.86 cm and 1.90 cm in diameter. Participants were seated at a table and presented with five rows of graded-height pegs.

Pegs were laid in a random order on the table prior to the board. The same time-keeper counted down “3, 2, 1, go” and the participant picked up one peg at a time and inserted them as quickly as possible into the board. Participants received one familiarisation trial using both hands. Completion times in seconds for three further (i.e. critical) trials were recorded for data analysis: right hand only, left hand only and both hands, with a 30 second rest period in-between trials. A researcher made note of the time to completion.

Wall catch test

Participants stood with feet parallel and shoulder width apart behind a line marked 2 m from a solid wall. A bucket of tennis balls were available directly in front of the participant and a ball was held in the dominant hand. A time-keeper counted down “3, 2, 1, go” at which point the ball was thrown underarm off the wall and the return was caught in their opposing hand. The participant then continued to throw and catch the ball in alternative hands for 30 seconds. If a ball was dropped participants were instructed to reach into the bucket of balls and to continue the test as quickly as possible. Feet remained behind the line at all times and catches were made one handed. Only caught balls were recorded; i.e., any returns trapped against the body did not count. Participants were given the command “stop” after 30 seconds. A second researcher recorded the number of successful catches. Participants received one familiarisation trial, followed by two critical trials, with

30 seconds rest between trials. The mean number of successful catches for the two critical trials was used for data analysis. This type of test has been shown to elicit valid and reproducible results in table tennis (4) showing an ICC of 0.88 and smallest detectable differences (SDD) of 0.8 m ($p < 0.001$).

Procedure

All experimental procedures were approved by the Institutional Ethics committee prior to testing (approval number SPA-REC-2012-007). All tests were conducted in the morning and participants attended one testing session lasting approximately one hour. The same investigator administered all the tests. The order of the four tests was randomised for the participants using playing cards. Participants that wore refractive correction to play sport were tested whilst wearing their current prescription. The ambient light in the room was carefully controlled and set at 420 Lux (22) using a Lux light meter (CEM DT-1300, Shenzhen, China).

All participants received a demonstration and standardised explanation of all tasks before testing. Some studies recommend familiarisation trials as strategies to prevent any presence of learning curves for the collection of EHC data (27-29). To the authors knowledge there are currently no validated/published protocols to eliminate familiarisation for the Graded Pegboard or Batak Pro™ tasks. Therefore, performances on the first trial of each task (the first two trials in the case of the short duration SVT™ task) were regarded as familiarisation, and the mean performances on the remaining trials were analysed.

Statistical Analysis

Results for all four tasks were converted into a standardised "hits per second" score, such that a higher number of hits per second on each task represented better performance. A Pearson product-moment correlation analysis was used to determine the relationships between the four EHC tasks (SVT™, Batak Pro™, wall catch test, and Graded Pegboard). A correlation coefficient above 0.10 represented a weak association, above 0.30 represented a moderate association, and above 0.50 represented a strong association between the tests (30). The proportion of variance shared between two tests was calculated as the square of their bivariate correlation coefficient r^2. A criterion alpha level of $p < 0.05$ was used to determine statistical significance. All statistical procedures were conducted using SPSS v22 statistical software (IBM, Chicago, USA).

Results

Table 1 summarises the raw performance scores for the four tests administered.

Insert Table 1 about here

Table 2 provides a summary of the analyses based upon the standardised scores for each task. Four correlations were identified as statistically significant, but only two were of moderate or greater strength. The strongest correlation in Table 2 was observed between the Batak Pro™ and the SVT™ (r^2 = 29%), whilst with regard to the confidence intervals shown, for the lower limit r^2 = 14.1% and for the upper limit r^2 = 45.7%. A moderate correlation was observed between the Batak Pro™ and the wall catch test (r^2 = 12%), with r^2 = 2.76% for the lower limit and r^2 = 26.6% for the upper limit. The remaining four intercorrelations were weak with none of the r^2 values for shared variance shown in Table 3 exceeding those already reported.

[*Table 2 & 3 about here*]

Discussion

Relationships between performances on four tests of EHC were examined to evaluate whether a general EHC ability underpinned performance on these tests. Identifying whether EHC is a general ability has important implications for coaches and sport scientists designing training programmes for athletes. Consistent with the majority of research on general motor ability (12, 13, 14) and Henry's specificity hypothesis (8), intercorrelations between performances on the four tasks were mostly weak. Only the correlation between the SVT™ and the Batak Pro™ could be categorised as strong, and it should be noted that these two tests utilise highly similar procedures, differing only in the number and location of targets to be hit. Overall, therefore, the results cast doubt over the existence of a general EHC ability underpinning performance on the selected generic EHC training devices. Consequently, these findings question the rationale for generic EHC training devices.

The generally weak correlations observed within the current study are somewhat at odds with the findings of Vesia et al. (19). Given the similarity in age, educational background and experience with the tests of the participants in the current study and that of Vesia, the differing results may be due to some difference in the protocol of the testing. The obvious difference is in the use of the Dynavision™ within Vesia et al.'s experiment, compared to the SVT™ and Batak Pro™ within the current experiment. However, all three devices operate on the same principles of reaching for randomly presented targets, with differences in the size, number (8-80) and location of potential targets between models. Alternatively, the different findings may be due to the tasks used by Vesia et al. (19) being, for the most part, of longer duration than the tasks used in the current study. That said, it is not clear why differences in task duration would influence the relationship between performances on differing tests of EHC.

The general lack of association between tasks is consistent with Henry's theory of specific motor abilities (8). According to this theory, small differences between test demands have potentially large effects on performance due to the specificity of what is learned with practice. For example, among the studied tasks, the pegboard places a greater demand on accuracy of fine motor actions compared to performance on the Batak Pro™. The Batak Pro™ involves greater use of peripheral vision compared to the SVT™. The SVT™ presents a discrete, static stimulus, whereas the wall catch test requires the tracking and interception of a dynamic stimulus, although it should be noted that the wall catch test does not replicate a game situation and is not necessarily sport specific. Any of these differences may be responsible for the relative lack of association observed between tasks.

Some limitations of this study need to be acknowledged when interpreting the results. The use of a typical sample of healthy young adults means data may not transfer to other populations (e.g. individuals with cognitive and physical impairments), athletic populations (e.g. elite sport) or sports. For example, the assessment might lose its strength in a larger homogenous sample with an elite population regarding perceptual-motor skills. In addition, the present study identified and examined four EHC tests, but it should be recognised that other tests and devices are available purporting to measure EHC which could be included in future. This is important as the general lack of association between all the EHC tests may cast some doubt over the actual measures used as they all involve some variations of movement coordination.

While the present findings reject the existence of a general factor underpinning performance on the examined general EHC training devices, it is not possible to discount the existence of a general EHC ability altogether. Any act of EHC involves the complex integration of a number of distinct functions relating to the identification and tracking of a target, allocation of attention, and the planning, execution and monitoring of the interceptive movement (6). Furthermore, each of these operations are controlled by neural networks located in different brain structures (6). If EHC is viewed as the coordinated functioning of multiple sub-processes, then it is logical that measures of EHC ability are sensitive to variations in the task such as stimulus (e.g., static versus dynamic, the need for peripheral v central vision, etc.) or response features (e.g., gross versus fine motor control). According to this conceptualisation of EHC, transfer from basic laboratory tests of EHC to sporting tasks is predicted to be minimal unless the majority of neural processes are shared. Future research is required to confirm whether such shared processes are responsible for the identified relationship between performance on the wall catch test and table tennis performance (22).

In summary, this study has provided further evidence against EHC as a general ability. Consequently, and in contrast to the claims published by manufacturers, improvements on EHC training devices are unlikely to transfer directly to enhanced sporting performance when the principle of specificity is violated. Practitioners are encouraged to explore sport-specific assessment and training of EHC.

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Table 1

Raw performance scores for the tests administered (sec)

Performance measure		Mean	*SD*	Maximum	Minimum
SVT: mean of successful strikes over four trials		9.92	1.03	12.69	7.87
Batak: number of successful strikes on Trial Two		68.26	8.36	83.00	43.00
Graded pegboard: critical trial completion time in seconds	Left hand	35.95	5.38	49.31	22.40
	Right Hand	37.79	5.02	54.00	27.80
	Both	28.73	5.16	44.50	20.40
Wall catch: mean of successful catches over two trials		24.70	4.89	36.50	14.00

Table 2

Descriptive statistics and Pearson correlation coefficients for performances on four eye hand coordination tasks

Device	Mean (hps)	SD	Batak Pro™	SVT™	Wall Catch
Batak Pro™	1.14	0.14			
SVT™	2.04	0.21	0.540** [0.376, 0.676]		
Wall Catch	0.82	0.16	0.349** [0.166, 0.516]	0.207 [-0.023, 0.396]	
Pegboard	0.89	0.11	0.227* [0.035, 0.398]	0.219* [-0.033, 0.428]	0.164 [-0.028, 0.352]

Notes. hps: hits per second. *Correlation is significant at the 0.05 level. **Correlation is significant at the 0.01 level. Values in square brackets refer to bias corrected and accelerated bootstrap 95% confidence intervals. Mean and standard deviation (SD) values are in hits per second.

Table 3

Shared variance (r^2) for the sample correlation coefficients and the lower and upper limit coefficients for the 95% confidence intervals reported in Table 2

Task	Statistic	Batak Pro™	SVT™	Wall catch
SVT™	Sample correlation coefficient	.29	--	--
	Lower limit	.14	--	--
	Upper limit	.46	--	--
Wall catch	Sample correlation coefficient	.12	.04	--
	Lower limit	.03	.00	--
	Upper limit	.27	.16	--
Pegboard	Sample correlation coefficient	.05	.05	.03
	Lower limit	.00	.00	.00
	Upper limit	.16	.18	.12