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The specificity versus generality of ball-handling skills – Empirical evidence for a general ball-handling ability

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ABSTRACT

The purpose of this study was to investigate if ball-handling skills are specific and uncorrelated (i.e., motor specificity), or if they share an underlying ball-handling ability (i.e., motor generality). To empirically investigate this question, we had a sample of 201 adolescents perform 12 novel ball-handling tasks. Using confirmatory factor analysis, we showed that a model based on the assumptions of the generality perspective was superior to a model based on assumptions of specificity. The general ball-handling factor did significantly influence the performance on all 12 tasks, with factor loadings ranging between 0.39 and 0.79. The results and it's practical implications are discussed in relation to development of sport specific skills.

1. Introduction

In the current motor literature, the idea of general motor abilities has been dismissed for quite some time and textbooks and researchers instead favour the idea of motor skills as independent (i.e., uncorrelated) and specific (e.g., Schmidt & Lee, 2014; Sigmundsson, Trana, Polman, & Haga, 2017). While there are plenty of evidence for the specificity of *certain* motor skills (e.g., balance skills; see Ringhof & Stein, 2018), we believe that this might not be the case for ball-handling skill. We base this assumption on previous research on ball skills (see below) and the purpose of this study is thus to empirically test the hypothesis of a general ball-handling ability (GBHA) influencing performance on different ball-handling tasks.

2. Previous research

As indicated above, there is considerable support for the specificity perspective in the broader motor literature (see e.g., Smith, 1973), and particularly so in the area of balance. However, and partly due to a lack of studies and partly due to contradictory findings, the results are not so clear-cut when it comes to ball skills. In our review of the literature, we find studies reporting both high and significant correlations (e.g., Fumoto & Kumagai, 2014; Peng, Ward, Weidong, Sutherland, & Goodway, 2012) as well as non-significant or low correlations (e.g., Haga, Pedersen, & Sigmundsson, 2007; Pedersen, Lorås, Norvang, & Asplund, 2014) between different ball skills.

One possible explanation for the contrasting findings reported is that these studies have relied on bivariate correlations. The problem with this methodology is that measurement errors ("noise") become included in the calculations, which can lead to an

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underestimation of the correlation coefficients. In those rare studies where factor analytic principles have been employed on ball skills – and even though the primary purpose of these studies has not been to investigate the possibility of a GBHA – the results can be interpreted as indicative of an underlying ball-handling ability. For example, Höner, Votteler, Schmid, Schultz, and Roth (2015) analysed the results of nearly 70,000 male youth soccer players (12–15 years) on a German soccer test and found that all ball skills loaded significantly (between 0.27 and 0.63) on a common factor. Similarly, Faber and colleagues (Faber, Nijhuis-Van Der Sanden, Elferink-Gemser, & Oosterveld, 2015) identified a ball factor and a gross motor function factor when they analysed the Dutch perceptuo-motor skills assessment for table tennis (using data from 113 young table tennis players) with factor loadings for the ball tasks ranging between 0.72 and 0.78. In addition, research on children's fundamental movement skills (FMS) generally tend to support an underlying ball-handling factor (i.e., object control factor; e.g., Ulrich, 2000; Wong & Cheung, 2010) that is distinct from other FMS (i.e., locomotion skills), even though this distinction has recently been challenged (Garn & Webster, 2018).

The purpose of this study was to empirically investigate the question of generality or specificity regarding ball-handling skills. In doing so, we expand on previous research in a number of ways. First, we address the problems associated with relying on bivariate correlations by employing latent variable modelling. Second, unlike studies on FMS, our test battery consists of advanced ball-handling tasks and are product/outcome oriented rather than process oriented (i.e., acknowledging that the same task goal can be achieved with different movement solutions). Third, while previous research has relied on data from children (less than 15 years), we employed a sample of adolescents (15–20 years), which thus can provide some indication to whether the (possible) GBHA found in younger children is also present in an older age group. Finally, and most importantly, we use a more comprehensive task battery – which includes ball tasks that are performed using hand/arms, feet/legs, rackets, and clubs/sticks – than the aforementioned factor analytic studies (i.e., Faber et al., 2015; Höner et al., 2015).

3. Method

3.1. Participants

In order to recruit participants, we contacted P.E. teachers working at different high schools via e-mail, asking if they and their classes would be interested in participating in the study. The classes/teachers that showed interest to participate were invited to perform the tests during their ordinary P.E lessons. In total, 201 individuals gave their consent to participate in the study (participation rate per class ranged between 48% and 100% with a mean of 81%). The participants were between 15 and 20 years of age (M = 16.27, SD = 0.79) and 108 were females, 85 males, one identified as "other", and seven individuals did not state their sex.

In terms of previous ball sport experience the sample was skewed towards low experience (See Fig. 1). This was measured by the aggregated number of years the participants had been involved in ball sports/activities (e.g., soccer 4 years, tennis 3 years, floorball 6 years = 13 years of experience). Mean experience was 7.7 years (SD = 8; Min = 0, Max = 55).

The study was conducted following the Swedish Act concerning the Ethical Review of Research Involving Humans (SFS,

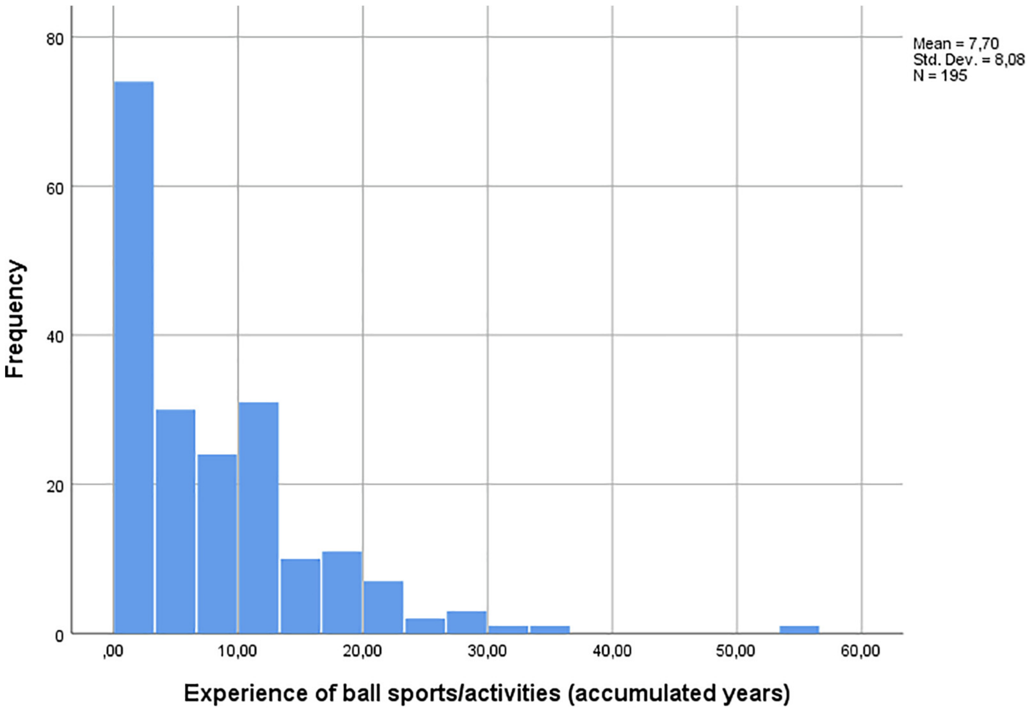

Fig. 1. Previous ball sport experience of the participants in the sample.

2003:460), and its amendments (SFS, 2008: 192), which is built on the Declaration of Helsinki and the Council of Europe's Convention for the protection of Human Rights. In accordance with the Swedish acts, the study did not have to undergo an ethical review as the study was not considered to have any psychological or medical impact on the participants, nor were any information that could identify individuals collected. The participants were given information about the purpose of the study, that all participation was voluntary, that they could cancel participation at any time during the test, and that all results would be anonymous.

3.2. Instruments

All the tasks that we used in this study were specifically developed for the present research project, which is a part of a larger research program on ball skills (Mamba – Measuring and Modelling Ball Skills). The development of the tasks – grounded in literature, discussions with practitioners (e.g., coaches, P.E teachers), own reflections – was based on the following premises.

First, we believed that ball-handling skills were best reflected by how well individuals could handle balls in motion. Balls were further defined as a sphere object that can bounce, hence American footballs and other non-spherical objects were excluded. Second, to develop tasks that tapped into different aspects of ball-handling, we took a point of departure in the way balls can be, and are allowed to, be handled in (popular Scandinavian) ball sports. Here four "clusters" were identified: feet/legs (e.g., soccer), hands/arms (e.g., basket, handball), racket/bat (e.g., tennis), and club/stick (e.g., hockey, golf).

Third, the tasks should be product oriented (i.e., focusing on the outcome), rather than process oriented (i.e., focusing on how the task is done) in order to acknowledge that task goals can be achieved with different movement solutions, and also in order try to remove subjectivity (i.e., evaluations by test administrators). Furthermore, unlike common tests of object control in children, the task should tap into more advanced ball handling skills. This was perceived as particularly relevant as the test is aimed at adolescents (and adults).

Fourth, although all task in the battery to some extent involved physical fitness abilities (Fleishman, 1964), efforts were made to avoid tasks that relied too much on such abilities (e.g., agility, flexibility, dynamic or static strength). This meant that tasks like dribbling courses on time (i.e., running while dribbling), rhythmic gymnastics tasks (e.g., trapping the ball between a foot and neck), and throwing for distance/velocity were excluded. We also deliberately tried to avoid tasks that were similar to sport specific skills and where performance required sport specific technique (e.g., topspin tennis serve). This was also considered important in order to develop task that were novel to the participants.

Approximately 50 tasks were developed in an initial pool of tasks, which we then used in two pilot studies (PS1, n = 38, PS2, n = 6). The main purposes of the pilot studies were to test the tasks in terms of practicability ("tweaking" of the tasks); to see what instructions that were required to be able to perform the tasks; how long they took to perform; and how to best arrange the tasks in the sports arena.

The process of selecting task for the final test battery was based on observations from the pilot studies and seminars/discussion with practitioners. The decisions were also made based on attaining task variability. This was achieved by including three tasks from each "cluster" (i.e., feet/legs, hands/arms, rackets, clubs/sticks) but at the same time avoid too similar tasks within each cluster (i.e., achieve within "cluster" variability).

The final test battery thus consisted of 12 novel, product oriented, ball tasks, where all tasks (except task 9) involved the ability to handle balls in motion. Task 9, which rather involved setting a ball in motion than handling a ball in motion, was included based on discussions with practitioners who purported that good golfing skills would be indicative of good ball-handling skills. The tasks in the battery have not yet undergone any formal test-retesting procedure.

3.2.1. The tasks

Task 1. *Objective*: The objective of the task was to hit a tennis ball, using a tennis racket, as many times as possible over a beam in 20 s. *Procedure*: The beam was placed 20 cm over the participants head (by a test supervisor) before the task started. The ball was allowed to be played at volley or after bouncing on the floor. It was also allowed to juggle the ball at the racket, but not to "rest" the ball on the racket (and "fling it" over the beam). If the ball was judged as unplayable (e.g., hit a wall, got outside the task area, rolling/lying on the floor) the attempt was stopped, even if the 20 s was not up, and the score up till that point was counted. *Number of attempts*: One. *Outcome measure*: The number of times the ball passed over the beam.

Task 2. *Objective*: To juggle a volleyball as many times as possible on the elbow/back side of forearm. *Procedure*: Participants were free to decide what arm to use (i.e., dominant, non-dominant) and had the option to alter between right and left arm during the try (in reality, however, this was not practiced by any participant). The task was performed within a restricted area of 2x2 meters marked by floorball rims. If the ball got outside of this area and couldn't be reached by the participant, the attempt was stopped, and the score up till that point was counted. *Number of attempts*: Three. *Outcome measure*: The number of correct juggles.

Task 3. *Objective of the task*: To throw and catch a tennis ball as many times as possibly against a wall in 20 s. *Procedure*: The participants were to throw the ball with one hand, and catch it with the other, against an upright table tennis table. The distance to the table tennis table was 2 m. If the participants failed to correctly catch the ball or missed the table tennis table, the attempt was stopped, even if the 20 s was not up, and the score up till that point was counted. *Number of attempts*: Two. *Outcome measure*: The number of correct catches.

Task 4. *Objective of the task*: To juggle a volleyball with the feet against a wall as many times as possible. *Procedure*: The task started with the participant kicking the ball against the wall (or throwing the ball against the wall, which then was not counted as a "juggle" in the results). After the ball had hit the wall it had to bounce one time in a specified area on the floor before being kicked again, and this "cycle" were to be repeated as many times as possible. The area (length = 1.1 m, width = 0.8 m) where the ball was to bounce was defined by floorball rims on two sides and a metal rod that was placed 1.1 m from the wall. The participants had to stand behind this rod, but were allowed to have their foot in the air above the area. Both feet were allowed to be used. *Number of attempts*: Three. *Outcome measure*: The number of times the ball hit the wall.

Task 5. *Objective of the task*: The objective of the task was to stop/control a tennis ball in flight and place it in a goal area (i.e., a hula-hoop taped on the floor) using a hockey stick. *Procedure*: The tennis ball was fired from an automatic tennis ball launcher (Tennis Tutor Pro Lite) and the participant stood beside the hula-hoop, which was positioned 13.2 m from the ball launcher. The balls – which were shot with a constant rate of one ball every two seconds and held an average velocity at the ball launcher of 24 m/s and 18 m/s at the target area – bounced one time in the floor before it reached the "goal area". In order to be counted as a correct attempt, the ball had to stay within the hula-hoop. However, once a ball had been counted as a "goal", the participants were allowed to remove it from the hula-hoop (for it to not interfere with the upcoming balls). Participants were further allowed to try to get the ball into the goal area even if a first trapping attempt was unsuccessful (and the ball bounced out of the hula-hoop). In reality, however, this was hard to achieve as you unless you were able to this very quickly (This "technique" can be seen in the video presentation of the task, performed by a highly experienced hockey player who also had performed the task multiple times). A correctly scored goal was awarded three points. A "hit but miss" (i.e., the ball was stopped but failed to stay within the goal area) was awarded one point. *Number of attempts*: One. (An attempt consisted of 10 balls after two familiarization balls). *Outcome measure*: The number of points achieved.

Task 6. *Objective of the task*: To juggle a volleyball as many times as possible using only knees/thighs. *Procedure*: The task was performed within a restricted area of 2x2 square meters and the participants were allowed to keep the ball in the air using either one or both knees/thighs (e.g., all juggles on right/left knee/thigh, or using right and left in random order). If the ball came outside of the restricted area, the attempt was stopped, and the score up till that point was counted. *Number of attempts*: Three. *Outcome measure*: The number of juggles, with a limit set at 40 juggles.

Task 7. *Objective of the task*: The objective of the task was to bounce a volleyball as many times as possible in a particular order in 20 s. *Procedure*: The task took place on a 1.2 × 1.2 square meters wooden platform with four equally sized squares. 4.5 cm × 4.5 cm wooden beams demarcated the squares. All squares were "blank", but for illustrational purposes, we can call these squares A, B, C and D here. The participants (who stood in the D-square) were to bounce the ball in the order of A, B, C, B, A and so forth (or C, B, A, B, C, if one so wished) as many times as possible in 20 s. Points were awarded every time the ball was bounced *twice* in a square and in the correct order. If the ball only bounced one time, no points were given but the task continued. It was also allowed to bounce the ball more times than two in a square, but only one point was still given for that square. It was not allowed to move the ball to the upcoming square by putting the hand under the ball. If the participants lost control of the ball, the attempt was stopped, and the score up till that point was counted. *Number of attempts*: Two. *Outcome measure*: The number of squares achieved in 20 s.

Task 8. *Objective of the task*: The objective of the task was to balance a ball as long as possible on a softball bat (length 71 cm, thickest circumference 17 cm, grip area 26 cm). *Procedure*: The participants placed the ball on the far end of the bat with their "free" hand (and their other hand placed in the grip area) and let go of the ball when the test supervisor said "go". The ball was a foam rubber ball with a diameter of 21 cm with a microcontroller and a motion sensor device placed inside the ball. This device stopped a timer (which was started by the test supervisor on the "go" command) when the ball hit the floor. *Number of attempts*: Three. *Outcome measure*: The time it took from the "go" command until the ball hit the floor.

Task 9. *Objective of the task*: To score as many points as possible on a miniature golf course. *Procedure*: The participants should hit a "goal zone" on a miniature golf course, which was specifically developed for this project. The course was 1 m in with and 2.45 m long. Distance from "tee" to the goal zone was 2.3 m. The goal zone consisted of five equally sized compartments, with the one in the middle awarding three points, the two next to the middle giving two points, and the two outer compartments awarding one point. The compartments were 9.4x10 cm^2 and separated by 2 mm thick walls. Three balls were put on specific markings on the course and played each at a time, and this was repeated one more time so that the participants played six balls. *Number of attempts*: One. *Outcome measure*: The number of points achieved.

Task 10. *Objective of the task*: The objective of the task was to dribble/move a soccer ball as fast as possible between two marking lines ten times. The markings were 1.2 m apart. *Procedure*: The ball was placed next to one of the markings and on a "go" command the participants were to move the ball as quickly as possible to the other marking and back, repeating this five times. A Kinect camera and specifically developed software was used to record the time. *Number of attempts*: One. *Outcome measure*: The time it took to complete ten dribbles.

Task 11. *Objective of the task*: To stop/control a falling table tennis ball using a standard table tennis bat and to successfully place the ball in a "goal". *Procedure*: The ball was automatically released from tube at a height of 1.6 m and the participants were allowed to "catch" the ball in mid-air or after it had bounced (one or more times) on the floor. The ball was then to be placed in a "goal" (the mouth of a tube with 5 cm in diameter) placed 0.9 m above the floor. The maximum allowed time for a try was set to 15 s. *Number of attempts*: Seven. *Outcome measure*: The fastest time of the attempts.

Task 12. This task was identical to Task 10, only that a (type of hockey) stick and a floor ball was used.

3.3. Procedure

The testing took place during the classes regularly P.E lesson. Before the testing started, we informed the participants that the purpose of the session/study not was to grade or rank how "good" they were at ball skills, but rather to see how they performed on different ball tasks. They were further told that they could do the tasks either in pairs or individually (most did so in pairs) and that they were not allowed to perform (or "try") a task if a test administrator was not present. We also encouraged the participants to do their best, be careful with the equipment, and to have fun. The P.E. teacher was present during the whole session.

The 12 tasks were arranged in an indoor sports arena (30 m × 32 m) in such way that each task could be performed without interference from any other tasks. No particular order for the tasks was followed, rather the participants were told to seek up tasks that were "free" (to avoid queues). This procedure was mainly due to that there were "only" seven test administrators (including the first three authors of this paper) to manage all twelve tasks. Each participant was given a list (numbered 1–12) where they could "tick off" the tasks they had completed. The participants were also encouraged to fill in a questionnaire (demographic information etc.) in between task.

When the participants arrived at a task, a test administrator gave them standardized instruction for that particular task. Although no formal test trails were allowed, the participants' were allowed to familiarize with a task in order for the test administrator to confirm that they had understood the task correctly.

For all data collection, we used an app specifically developed for this research program. For task 1–7 and 9, we counted the participants' scores and fed the results manually into the app. For task 8 and 10–12, the results were automatically fed into the app (See appendix for a description of the technology used for these tasks).

As the testing were to take place during the high school students' ordinary P.E lessons, we had to set some limitations on the tasks to ensure that completion of the whole test battery would be possible within the lesson time. This included limitation for some tasks on the maximum number of repetitions, the number of attempts, or the time allowed for a task (see more detailed information in the presentation of the tasks). Decisions on which tasks to impose limitations on was informed various factors such as; the difficulty of the task, the degree of instructions needed for a task, how long a task took to complete, and on what we believed would be the minimum of attempts needed to get a fair representation of individuals skill on that task (i.e., meaningful variation). This process did thus admittedly include some degree of arbitrariness.

3.4. Analysis

3.4.1. Data analysis

All data cleaning and preparation was done using SPSS Version 22 (IBM, Armonk, New York, USA). For tasks that allowed more than one attempt, we used the best attempt in all analyses. We reversed the scales for task 10, 11, and 12 (so they reflected that lower times meant better performance) in order to facilitate easier interpretations of the relationships between the tasks. (i.e., to avoid negative correlations). This was accomplished by subtracting each participant's value from the max value of that variable. Hence, the individual with the slowest time got a value of zero. A screening of the data matrix showed that two participants didn't have data on any of the tasks and were subsequently removed from the data set. After these participants' had been removed, missing data for the tasks ranged from 1% (3 cells) to 4% (9 cells), with a mean missing data for all tasks of 2%.

In order to determine if the variables met basic assumptions of normal distribution and linear bivariate correlations, we used histograms, scatterplots, descriptive statistics, and significance testing. Significance testing, using Shapiro-Wilks, showed that all variables deviated from a normal distribution ($p = .00$) and a further inspection of the skew values and the histograms indicated that data on eight of the tasks could be considered as being highly skewed (skew values > 1; Bulmer, 1979). Five had positively and three had negatively (the three reversed task scores) skewed distributions. This is a common problem when using performance variables on ratio scales as they are bounded by zero (Nevill & Lane, 2007). This was also indicative of floor effects (i.e., tasks being too difficult for many of the participants) in the five positively skewed task, and ceiling effects for the negatively skewed tasks (i.e., there is a limit to how fast you can perform a tasks).

It is known that skewed variables cause non-linearity, which in turn leads to an underestimation of the product-moment correlation. This is especially the case when one variable is negatively skewed and the other is positively skewed (Dunlap, Burke, &

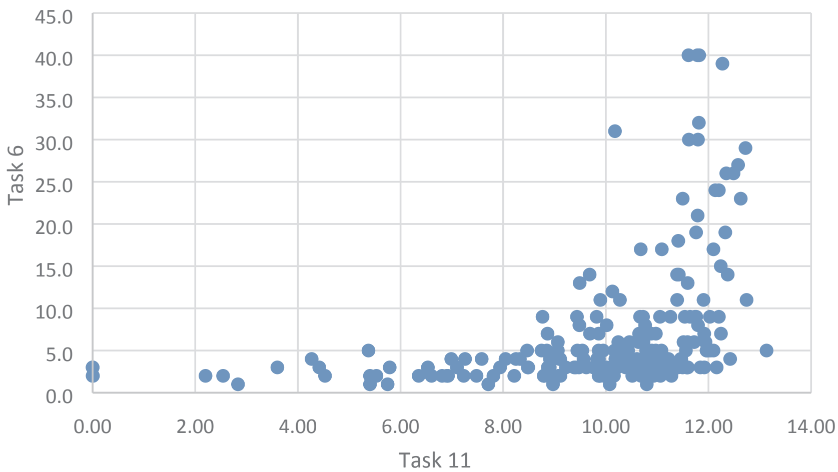

Fig. 2a. Scatterplot for Task 6 and Task 11 *before* logarithmic transformations ($r = 0.40$, $p < .001$).

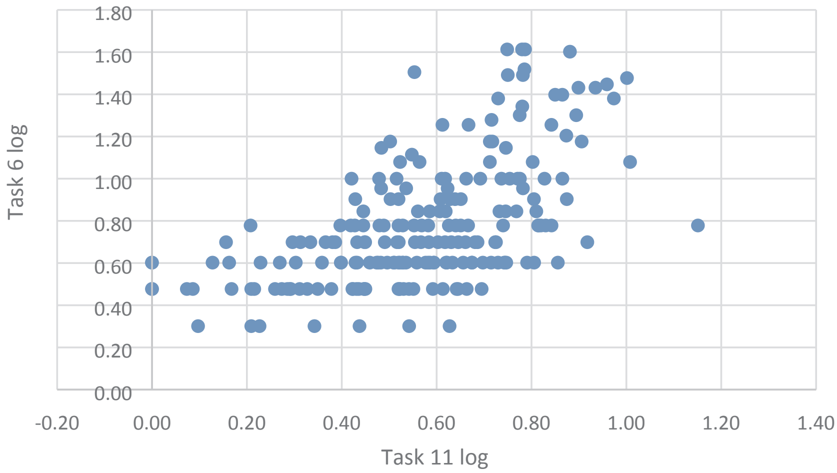

Fig. 2b. Scatterplot of Task 6 and Task 11 *after* logarithmic transformations (r = 0.58, $p < .001$).

Greer, 1995). This statistical artefact was found for a number of relationships in our data, and an example of this is provided in the scatterplot in Fig. 2a. Therefore, logarithmic transformations were performed on all the highly skewed variables (Nevill, 1997). Although all but one of the re-expressed variables still were significantly skewed after this procedure, this reduced the skewness value to less than 1, hence the distributions became more moderately skewed (Bulmer, 1979). Another task (5) also had a skewness value > 1, but log transforming this variable lead to a similar (> 1), but negative skewness value. After consulting the histogram for the distribution of the variable, we decided not to transform this variable. The logarithmic transformations led to an increased linear relationship between previously skewed variables, as is illustrated in Fig. 2b.

3.4.2. Statistical analysis

To test which of the two different perspectives (i.e., specificity and generality) that best could explain the relationships between the tasks used in the study, we specified two separate models. In Model 1, the relationships between all ball tasks were assumed to be zero (i.e., a null model) and this model hence tested if the ball task were to be considered as independent (i.e., non-correlated). In Model 2, we set all tasks to be predicted by a general latent factor (GBHA), and it thus tested the assumptions made in the generality perspective of a general ability underlying performance on various ball tasks.

To evaluate how well the proposed models fitted the data, we used four different fit indices; χ^2/df, Root Mean Squared Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Standardized Root Mean Square Residual (SRMR). Marsh (2007) proposed that values of 0.95 and 0.90 for CFI and 0.5 and 0.8 for RMSEA reflect excellent respective acceptable fit, and for SRMR, Hu and Bentler (1999) have suggested that values close to or below 0.08 indicate that the data fit the specified model.

We conducted all main analyses using Mplus 8 (Muthén & Muthén, 1998–2017) and used the robust Maximum Likelihood (MLR) estimation method to handle that the variables deviated from a normal distribution. In Mplus, missing data is by default replaced with maximum likelihood estimations that are derived from modelling of the existing data.

4. Results

4.1. Descriptive statistics

We report descriptive statistics for the twelve tasks in Table 1 and the correlations between tasks is provided in Table 2.

4.2. Main results

We first tested Model 1 (the specificity hypothesis) which was shown to have a poor fit with data (χ^2 = 976.374, p = .00, df = 66; RMSEA = 0.263, CI_{90} 0.249–0.278; CFI = 0.00; SRMR = 0.386) and the idea that the different tasks in the study were independent was thus not supported. The lack of fit between data and Model 1 instead suggested that there in fact were relationships between the tasks not specified in the first model.

Model 2 was shown to have an excellent fit between model and data (χ^2 = 67.26, $p < .11$, df = 54; RMSEA = 0.035, 378 CI90 0.000–0.060; CFI = 0.985; SRMR = 0.035), which strongly indicated the presence of a GBHA among the participants. As can be seen in Fig. 3, the factor loadings for the tasks on the latent factor (i.e., GBHA) ranged between 0.39 and 0.79 (all significant at p = .001). The GBHA thus significantly influenced the performance on all 12 tasks, but to a varying degree. For example, in Task 9 (miniature golf), only15 % of the variance was explained by the latent factor (GBHA). In contrast, GBHA explained as much as 60% of the variation in Tasks 1, 11, and 12. On average, the GBHA could account for 44% of the performance variation in the tasks.

Table 1
Descriptive statistics for the tasks used in the study.

Task	Min	Max	Mean	SD	Outcome measure	Attempts
1	0	12	3.7	2.8	Score	1
2	1	19	4.4	2.3	Juggles	3
3	0	26	8.9	6.9	Catches	2
4	0	18	3.1	2.9	Score	3
5	0	22	7.1	2.9	Score	1
6	1	40	6.5	7.2	Juggles	3
7	1	28	12.1	6.8	Bounces	2
8	0.608 s	8.83 s	2.29 s	1.35 s	Time	3
9	0	11	4.1	2.9	Score	1
10	8.69 s	44.1 s	18.86 s	6.34 s	Time	1
11	2.26 s	15 s	5.38 s	2.49 s	Time	5
12	5.67 s	36.63 s	12.93 s	4.86 s	Time	1

Note 1. The descriptive values for Task 10, 11, 12 are the original (non-reversed) values, thus Min is the fastest (best) time and Max is the slowest.

Table 2
Correlation matrix for the tasks used in the study.

Task	1	2	3	4	5	6	7	8	9	10	11	12
1	*0.067*											
2	0.459	*0.026*										
3	0.592	0.461	*47.83*									
4	0.369	0.353	0.367	*0.071*								
5	0.365	0.282	0.298	0.282	*8.75*							
6	0.626	0.496	0.569	0.352	0.396	*0.085*						
7	0.559	0.452	0.564	0.291	0.289	0.591	*45.86*					
8	0.556	0.421	0.487	0.312	0.380	0.500	0.463	*0.023*				
9	0.273	0.337	0.272	0.244	0.212	0.263	0.202	0.275	*8.79*			
10	0.514	0.447	0.534	0.417	0.361	0.575	0.400	0.452	0.262	*0.073*		
11	0.582	0.550	0.618	0.302	0.270	0.569	0.552	0.449	0.307	0.557	*0.042*	
12	0.604	0.485	0.617	0.400	0.419	0.533	0.512	0.489	0.335	0.637	0.644	*0.070*

Note. Variance for the tasks are in italics on the diagonal of the matrix.
The variance for task 1, 2, 4, 6, 8, 10–12 is on the log-transformed scale.

5. Discussion

The point of departure for this study was our reading of the motor literature, which suggests that generality or specificity of ball handling skills is not satisfactory answered. The purpose of this study was thus to empirically investigate if there is a GBHA that influencing the performance on ball-handling tasks or if ball-handling skills are independent and uncorrelated.

The results did strongly support the idea of a general ball-handling ability, as all the tasks included in the study were significantly influenced by a general underlying ball-handling factor. The fact that we did use ball-handling tasks of varying kind, which were also novel to the participants, strengthens this finding. We find further support for the existence of a GBHA in that Task 9, which did not fully match the definition of ball handling used in this study, had the weakest relationship with the GBHA.

Notwithstanding, an inspection of the estimates in Model 2 (Fig. 3) shows that the influence of the GBHA varied for the different tasks. Following a standard interpretation of factor analysis, this would be due to that the tasks differ in how much GBHA they require, but also due to factors not included in the model (i.e., the unexplained variance in the tasks). In this latter category, we believe that factors such as motivation, chance/luck, measurement mistakes, as well as some degree of task specificity influenced the participants' performance on the different tasks. Moreover, in the first step of learning a new skill/task, it has been suggested that a cognitive understanding of the task is crucial (i.e., the cognitive stage Fitts & Posner, 1967), and there is evidence linking intellectual abilities to the initial learning of a skill (e.g., see Ackerman, 2005). Given that the tasks used in this study were designed to be novel to the participants, and the low degree of previous ball sport experience in the sample, it likely that cognitive abilities could account for some of the unexplained variance in the tasks too.

To situate the findings from this study in relation to dominant theories of motor learning/skill acquisition (e.g., Schema Theory, Ecological Dynamics) is somewhat difficult. This is simply because most contemporary theories are built upon the idea of motor specificity, an idea the results from this study clearly challenge. Superficially, the role of general abilities could be seen as sharing some resemblance with General Motor Program for classes of similar motor skills, as has been suggested by Schema Theory (ST; Schmidt, 1975). However, according to ST, a class is "a set of goal-directed actions that all share similar underlying characteristics, or "form," such as relative timing relationships" (Keetch, Lee, & Schmidt, 2008, p. 724), and overarm throwing is used as an example. Noticeably, the tasks used in this study represent a class of actions that are much more diverse (e.g., using feet, arms, equipment) than that suggested in ST.

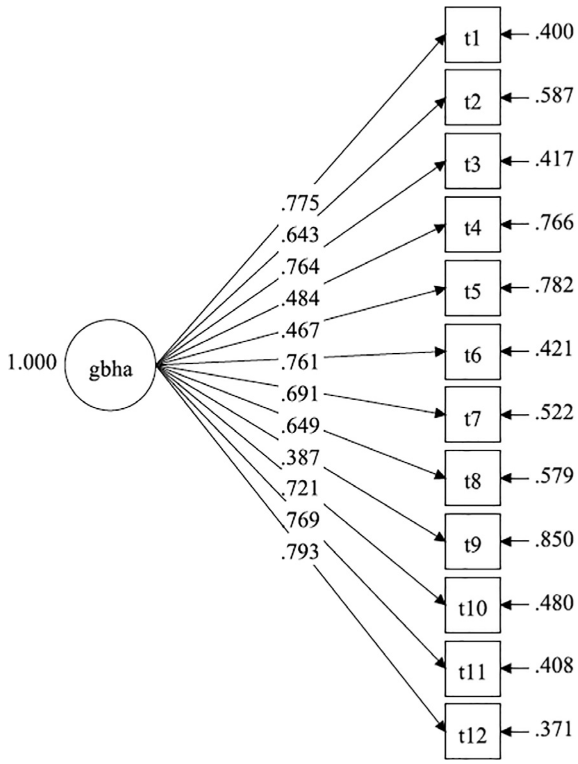

Fig. 3. The standardized coefficients from Model 2. All factor loadings are significant at $p < .001$.

The results from this study are nevertheless in line with previous studies on FMS that show a general ability (i.e., object control factor) underlying ball skill in young children (Ulrich, 2000; Wong & Cheung, 2010) pointing to that this ability is also present in adolescents. Hence, it seems that GBHA/object control is not related to maturity, but rather a stable trait of individuals as suggested by the literature on motor abilities (e.g., Fleishman, 1964). With that said, the relatively low experience of ball sports among the sample in this study needs to be taken in consideration when interpreting of the results. There is a possibility that experience mediates the importance of GBHA on ball handling tasks, where more experience could diminish the role of GBHA, although this needs to be empirically tested.

The idea of a GBHA/object control factor as a stable trait is quite neglected in texts and studies on FMS. Instead, the role of "nurture" (appropriate practice, instructions etc.) is emphasized in the development of mature FMS (e.g., Lubans, Morgan, Cliff, Barnett, & Okely, 2010). Meta analytic results of intervention studies also support this notion (even though object control skills seem to be more difficult to improve than locomotion skills; see Morgan et al., 2013). Still, to the best of our knowledge, these conclusions have been made based on analyses using composite measures of object control skills and where "noise" thus is included. Therefore, it is not possible to know if the improvements are due to an actual increase in the participants GBHA (i.e., object control factor) or due to other factors, such as the ones discussed above (e.g., motivation, task specificity). To answer this question, multiple group latent variable modelling could be a possible method. This would make it possible to investigate mean differences in the GBHA (i.e., latent variable) between pre- and post-tests, as well as to see if the influence of the GBHA on performance diminishes with practice (i.e., changes in factor loadings). This would provide valuable information on the role of the GBHA in the development of ball skills in children and adolescents.

Furthermore, the results from this study provide no information on how GBHA is related to the development of "real world" sport skills. Interpreting the results from the present study in the light of previous studies can however provide some insights on the matter. Higher factor loadings have been reported in studies using more generic ball tasks (such as the present study and Faber et al., 2015) than in studies involving sport specific tasks (e.g., Höner et al., 2015). This indicates that the influence of this (possible) GBHA is greater for more basic ball tasks than for sport specific tasks (which often require sport specific technique). Future research in the area could test this assumption by using latent variable modelling on test batteries including both sport specific and generic ball tasks. If we were to speculate further, it is conceivable that this (possible) GBHA is driving the development of the sport *specific* skills needed for high-level performance. Some current research can be interpreted as in favour of this. Faber and colleagues (Faber, Elferink-Gemser, Faber, Oosterveld, & Nijhuis-Van der Sanden, 2016) showed that the ball skills in the Dutch perceptuo-motor skills assessment could explain 50% of the variation in competition results two and half year later. Likewise, Höner and colleagues recently showed that the ball factor identified in their 2015 study (Höner et al., 2015) significantly predicted the performance level of 14,000 youth players as adult players (Höner, Leyhr, & Kelava, 2017).

5.1. Limitations

We would like to point to some limitations of the present study that should be considered when interpreting the results. First, the tasks that we used in this study are newly developed and have not yet undergone any formal test-retesting procedure, which affects our knowledge about the reliability of the tasks. Second, the restrictions that we did set on how many attempts that were allowed for the tasks might also have influenced the validity of the participants' scores (see e.g., Pedersen & Lorås, 2017). Given the rather few attempts that were allowed, there is thus a risk that the ball skills of participants were underestimated and that chance factors influenced the results. This concern was partly addressed by the fact that the participants were allowed some familiarization with the tasks and that we used the participants' best result, as advised by Pedersen and Lorås (2017).

In this study, the focus of investigation was ball skills and the idea of a GBHA, hence only ball tasks were included in the test battery. As a result, it is not possible to rule out the possibility that the general factor found in this study could also underlie other motor skills. That is, that the factor that was found corresponds to a Global Motor Ability for "sport skills", as has been suggested by some scholars (e.g., Liefeith, Kiely, Collins, & Richards, 2018). As speculated by Fleishman, "…a general factor often labelled as Gross-Body Coordination can be expected to appear when a number of complex sports skills tests (e.g., ball catching, soccer kicking) are included in a larger battery" (1964, p.35). We therefore call for future studies to investigate this possibility by using both ball skills and other motor skills in investigations in the area.

5.2. Practical implications

The findings from this study potentially have implications for talent identification/development (TID) as well as working with children/adolescent with motor problems/difficulties. In the light of previous results showing the importance of a ball handling ability for future performance in ball sports (i.e., Faber et al., 2016; Höner et al., 2017), the identification of individuals with high levels of GBHA seem to be a promising strategy in sports where good ball-handling skills are essential (e.g., table tennis). If, as discussed above, GBHA is a stable trait and thus unrelated to maturity, this would address one of the problems in TID, namely to separate talent/potential from maturity (Vaeyens, Lenoir, Williams, & Philippaerts, 2008). Furthermore, considering GBHA as a relatively stable trait also points to the importance of controlling for participants initial levels of GBHA when evaluating training programs designed to improve ball-handling skills. This is mainly because it is likely that individuals with a low or high GBHA respond differently to different training regimes.

The results also carry implications for interventions aimed at children and individuals with motor difficulties/impairments (e.g., Developmental Coordination Disorder; DCD). Although individuals with DCD form a heterogeneous group in terms of types of motor difficulties, ball skills are often reported as a particularly problematic area (Magalhaes, Cardoso, & Missiuna, 2011). For children with DCD, meta-analytic findings have shown that "task oriented" or "specific skills" training is more effective than more generalized training programs, such as "process oriented" training or, classical physical therapy (Pless & Carlsson, 2000; Smits-Engelsman et al., 2012). Even though this might seem to contradict the idea of generality, it is actually supporting the ability perspective. The interpretation would then be that for individuals with low levels of GBHA (such as those with DCD) training on one particular ball skill/task would lead to improvements on that particular skill/task, but not transfer to other ball tasks (while the reverse applies to individuals with higher levels of GBHA). Training on many different skills/tasks simultaneously would not lead to a general improvement in GBHA, as it is a stable trait. Therefore, we hypothesize that when working with individuals with low(er) levels of GBHA, training should focus on the particular ball skills that are to be developed, rather than providing a "smorgasbord" of tasks/activities and expect general improvements.

References

Ackerman, P. L. (2005). Ability determinants of individual differences in skilled performance. In R. J. Sternberg, & J. E. Pretz (Eds.). *Cognition and intelligence: Identifying the mechanisms of the mind* (pp. 142–159). New York, NY: Cambridge University Press.

Bulmer, M. G. (1979). *Principles of statistics.* New York: Dover Publications.

Dunlap, W. P., Burke, M. J., & Greer, T. (1995). The effect of skew on the magnitude of product-moment correlations. *The Journal of General Psychology, 122*(4), 365–377.

Faber, I. R., Elferink-Gemser, M. T., Faber, N. R., Oosterveld, F. G., & Nijhuis-Van der Sanden, M. W. (2016). Can perceptuo-motor skills assessment outcomes in young table tennis players (7–11 years) predict future competition participation and performance? An observational prospective study. *PloS one, 11*(2), e0149037.

Faber, I. R., Nijhuis-Van Der Sanden, M. W. G., Elferink-Gemser, M. T., & Oosterveld, F. G. J. (2015). The Dutch motor skills assessment as tool for talent development in table tennis: A reproducibility and validity study. *Journal of Sports Sciences, 33*(11), 1149–1158.

Fitts, P. M., & Posner, M. I. (1967). *Human performance.* Belmont, CA: Brooks/Cole.

Fleishman, E. A. (1964). *The structure and measurement of physical fitness.* Englewood Cliffs: Prentice-Hall.

Fumoto, N., & Kumagai, K. (2014). Does a player whose ball juggling skill is the best shows the best ability in a soccer game?: A consideration of the validity of skill tests from a new viewpoint keeping utility in mind. *Football Science, 11*, 18–28.

Garn, A. C., & Webster, E. K. (2018). Reexamining the factor structure of the test of gross motor development–second edition: Application of exploratory structural equation modeling. *Measurement in Physical Education and Exercise Science, 22*(3), 200–212.

Haga, M., Pedersen, A. V., & Sigmundsson, H. (2007). Interrelationship among selected measures of motor skills. *Child: Care, Health and Development, 34*(2), 245–248.

Höner, O., Leyhr, D., & Kelava, A. (2017). The influence of speed abilities and technical skills in early adolescence on adult success in soccer: A long-term prospective analysis using ANOVA and SEM approaches. *PLoS ONE, 12*(8), e0182211.

Höner, O., Votteler, A., Schmid, M., Schultz, F., & Roth, K. (2015). Psychometric properties of the motor diagnostics in the German football talent identification and development programme. *Journal of Sports Sciences, 33*(2), 145–159.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1–55.

Keetch, K. M., Lee, T. D., & Schmidt, R. A. (2008). Especial skills: Specificity embedded within generality. *Journal of Sport and Exercise Psychology, 30*(6), 723–736.

Liefeith, A., Kiely, J., Collins, D., & Richards, J. (2018). Back to the Future – in support of a renewed emphasis on generic agility training within sports specific developmental pathways. *Journal of Sports Sciences, 36*(19), 2250–2255.
Lubans, D. R., Morgan, P. J., Cliff, D. P., Barnett, L. M., & Okely, A. D. (2010). Fundamental movement skills in children and adolescents. *Sports Medicine, 40*(12), 1019–1035.
Magalhaes, L. C., Cardoso, A. A., & Missiuna, C. (2011). Activities and participation in children with developmental coordination disorder: A systematic review. *Research in Developmental Disabilities, 32*(4), 1309–1316.
Marsh, H. W. (2007). Application in confirmatory factor analysis and structural equation modeling in sport and exercise psychology. In G. Tenenbaum, & R. C. Eklund (Eds.). *Handbook of sport psychology* (pp. 962). (3. ed.). Hoboken: John Wiley & Sons, Inc.
Morgan, P. J., Barnett, L. M., Cliff, D. P., Okely, A. D., Scott, H. A., Cohen, K. E., et al. (2013). Fundamental movement skill interventions in youth: A systematic review and meta-analysis. *Pediatrics, 132*(5), e1361–e1383.
Muthén, L. K., & Muthén, B. O. (1998-2017). *Mplus user's guide* (8th ed.). Los Angeles, CA: Muthén & Muthén.
Nevill, A. M. (1997). Why the analysis of performance variables recorded on a ratio scale will invariably benefit from a log transformation. *Journal of Sports Sciences, 15*, 457–458.
Nevill, A., & Lane, A. (2007). Why self-report ''Likert'' scale data should not be log-transformed. *Journal of Sports Sciences, 25*(1), 1–2.
Pedersen, A. V., & Lorås, H. (2017). When is a test score fair for the individual who is being tested? Effects of different scoring procedures across multiple attempts when testing a motor skill task. *Frontiers in Psychology, 8*, 619.
Pedersen, A. V., Lorås, H., Norvang, O. P., & Asplund, J. (2014). Measuring soccer technique with easy-to-administer field tasks in female soccer players from four different competitive levels. *Perceptual & Motor Skills, 119*(3), 961–970.
Peng, Z., Ward, P., Weidong, L., Sutherland, S., & Goodway, J. (2012). Effects of play practice on teaching table tennis skills. *Journal of Teaching in Physical Education, 31*(1), 71–85.
Pless, M., & Carlsson, M. (2000). Effects of motor skill intervention on developmental coordination disorder: A meta-analysis. *Adapted Physical Activity Quarterly, 17*(4), 381–401.
Ringhof, S., & Stein, T. (2018). Biomechanical assessment of dynamic balance: Specificity of different balance tests. *Human Movement Science, 58*, 140–147.
Schmidt, R. A. (1975). A schema theory of discrete motor skill learning. *Psychological Review, 82*, 225–260.
Schmidt, R. A., & Lee, T. D. (2014). *Motor learning and performance: From principles to application* (5th ed.). Champaign, IL: Human Kinetics.
SFS (2003: 460). Lag om etikprövning av forskning som avser människor [The Act Concerning the Ethical Review of Research Involving Humans] (in Swedish).
SFS (2008: 192) Lag om ändring i lagen (2003:460) om etikprövning av forskning som avser människor. Stockholm: Socialdepartementet. [Law 2008:192 amending the Act (2003: 460) Ethical Review of Research Involving Humans].
Sigmundsson, H., Trana, L., Polman, R., & Haga, M. (2017). What is trained develops! theoretical perspective on skill learning. *Sports (Basel, Switzerland), 5*(38).
Smith, L. E. (1973). *Specificity versus generality of relationships between individual differences in motor abilities.* Educational Perspectives.
Smits-Engelsman, B. C. M., Blank, R., VanDer Kaay, A.-C., Mosterd-Van Der Meijs, R., Vlugt-Van Den Brand, E., Polatajko, H. J., et al. (2012). Efficacy of interventions to improve motor performance in children with developmental coordination disorder: A combined systematic review and meta-analysis. *Developmental Medicine and Child Neurology, 55*, 229–237.
Ulrich, D. A. (2000). *The test of gross motor development* (2nd Ed.). Austin, TX: Pro-ed.
Vaeyens, R., Lenoir, M., Williams, A. M., & Philippaerts, R. M. (2008). Talent identification and development programmes in sport. *Sports Medicine, 38*(9), 703–714.
Wong, K. Y. A., & Cheung, S. Y. (2010). Confirmatory factor analysis of the test of gross 694 motor development-2. *Measurement in Physical Education and Exercise Science, 14*(3), 202–209.