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ORIGINAL

THE ACCURACY OF MOTOR IMAGERY AND BALL RECEPTION IN CHILDREN

LA PRECISIÓN DEL MOVIMIENTO IMAGINADO Y LA RECEPCIÓN DE BALÓN EN NIÑOS

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ABSTRACT

Recent studies have found that motor imaginery is developed linked to the development of motor skills in children. The purpose of this study is to analyze how the motor imaginery of the principal elements to solve a motor problem (ball reception) relates to the motor skill levels in children (3-9 years). The sample consisted of 215 participants (87 boys and 118 girls), (M = 5.94, SD = 1.47).We used a mixed methodology: drawings, gestural prompts, verbalization of thought and a practical test of ball reception. The MANOVA revealed significant differences in the meta-cognitive abilities and motor function of the developmental stages. A structural equation analysis revealed that meta-cognitive abilities mediate the relationship between the stages of development and the ability in the reception of moving objects. Their implications in motor learning are discussed.

KEY WORDS: Motor development, motor skills, moving objects reception.

RESUMEN

Estudios recientes observaron que las imágenes motrices se desarrollan de forma entrelazada con el desarrollo de las habilidades motrices en niños. La finalidad de este estudio es analizar en qué medida la imagen motriz de los elementos necesarios para resolver un problema motor (la recepción de un balón), se relaciona con los niveles de habilidad en niños (3 - 9 años). La muestra estuvo formada por 215 participantes (87 chicos y 118 chicas), (*M* = 5,94, *DT* = 1,47). Se ha utilizado una metodología mixta: dibujos, indicaciones gestuales, verbalización del pensamiento y una prueba práctica de recepción de balón. El MANOVA reveló diferencias significativas en las capacidades meta-cognitivas y motrices en función de las etapas de desarrollo. Un análisis de ecuaciones estructurales reveló que las capacidades meta-cognitivas median la relación entre las etapas de desarrollo y la habilidad de recepción de móviles. Se discuten sus repercusiones en el aprendizaje motor.

PALABRAS CLAVE: Desarrollo motor, habilidades motrices, recepción de móviles

1. INTRODUCTION

The purpose of this study is to analyse how the conscious anticipation of the measures necessary to mentally solve a motor situation/problem relates to the skill levels in children aged between 3 and 9. The mental representation of a movement, or motor imagery, is a dynamic state whereby an individual mentally reproduces a specific motor action (Wilson, Maruff, Ives and Currie, 2001). Imaging and motor praxis ability studies indicate that imagined motor performance is subject to environmental and physiological limitations (Decety and Jeannerod, 1996; Jeannerod, 2001). For example, the time to complete motor movements in the imagination correlates highly with the time required for their actual execution (Courtine, Papaxanthis, Gentili and Pozzo, 2004). In a sporting context, this was especially evident in sports such as golf (Orliaguet and Coello, 1998) and badminton (Munzert, 2008). In addition, the logarithmic association established between speed and the accuracy of the actual movements (Fitts's Law) also extends to the movements imagined by normal individuals (Decety, 1996). All these results indicate a close relationship between the time taken in real and imagined situations. According to Munzert, Lorey and Zentgraf (2009), this relationship can be explained elegantly and simply through the proposal that motor imagery and motor execution are based on the overlapping of representations.

Mental rotation was another paradigm used to analyse this problem; it is a fundamental extension for understanding the duration of mental movements.

When the participants had to compare similar objects with different orientations, the execution time depended on the angular disparity between the objects; the greater the disparity, the longer the reaction time (Shepard and Metzler, 1971). With the acceptance that mental rotation tasks require mental simulation, the reaction time can be taken as a valid indicator for similar motor imagery and motor execution processes. Within this context, the results on the mental rotation of parts of or the whole body are compatible with the premise that motor execution and motor imagery have a common representation basis (see Zacks' meta-analysis, 2008).

Other research has centred on: the activation of cortical and subcortical areas during motor representation (Fourkas Bonavolontà, Avenanti and Aglioti, 2008; Kasess et al., 2008; Ramnani, 2006); motor imagery in patients with cerebrovascular injuries (Cicinelli et al., 2006; Sabaté, González and Rodriguez, 2007; Stinear Fleming, Barber and Byblow, 2007); and in patients with Parkinson's disease (Amick, Schendan, Ganis and Cronin-Golomb, 2006; Helmich, Lange, Bloem and Toni, 2007). In summary, these neural studies on mental representation have consistently found that activation patterns are common both to the mental simulation of a movement and to its actual execution. The hypothesis that neurocognitive networks are the same for both real and simulated movements is also supported by studies on patients with unilateral motor cortex damage. These links between actual and simulated movements can help to determine the nature of cognitive and motor deterioration in children with learning difficulties. Within this context, Maruff, Wilson, Trebilcock and Currie (1999) found evidence suggesting that the preparation and internal representation of volitional movements is affected in children with DCD (Developmental coordination disorder). It is important to point out that, since a decrease only occurred in the movements made in the imagination, it could not be attributed to the motor control output systems.

Mental training has been implemented in sport in order to learn motor skills. Mental practice of motor behaviour, such as the systematic and repetitive use of images, is considered a powerful tool for increasing learning capacity in sport. Several meta-analyses have revealed the systematic but moderate effect of mental training in motor learning (Hinshaw, 1991-1992; Richardson, 1967). Different mediators have been identified in the relation between mental training and motor performance; these include the skill level, the task's characteristics, the images and the distinction between an internal and external perspective.

Although motor imagery is a well documented phenomenon in adults, only a few studies have reported on the acquisition of motor images during childhood (Bouwien, Smits-Engelsman and Wilson, in print; Cecchini, Fernández-Losa and Pallasá, 2012: Choudhury, Charman, Bird and Blakemore, 2007). In general, these studies show how the accuracy of the simulated movement constantly improves during childhood, reaching an asymptote during adolescence and early adulthood. In order to observe and compare the metacognitive skills underlying motor performance in children with and without coordination development difficulties, two studies using the thought verbalisation method found that the former voiced inappropriate declarations related to planning and evaluation activities far more frequently (Martini, Wall and Shore, 2004; Lloyd, Reid and Bouffard, 2006). Caeyenberghs, Tsoupas, Wilson and Smits-Engelsman (2009) found that motor imagery development is linked to the development of motor skills in children. This is because motor images are the result of internal modelling processes that provide the basis for the adaptation of movements towards an object.

Based on this, the purpose of this study is to analyse how awareness or motor imagery of the elements necessary to solve a motor problem, in this case statically receiving a ball with the arms, influence skill levels in children aged between 3 and 9. In other words, we want to discover how the conscious anticipation of a moving object’s trajectory, from its temporal structure and impact area, as well as the motor programme that includes the adjustments necessary to mentally solve the situation/problem has a bearing on motor skill levels at these ages.

2. MATERIAL AND METHOD

2.1. PARTICIPANTS

215 students (87 boys and 118 girls) from an Infant and Primary School, aged between 3 and 9 (*M* = 5.91, *ST* = 1.48), took part in this study. Students were in the three Infant Education grades and three Primary Education grades.

	Boys		Girls	
Age	No.	M(SD)	No.	M(SD)
3-4 years	13	3.54 (0.21)	22	3.51 (0.20)
4-5 years	15	4.57 (0.27)	18	4.36 (0.25)
5-6 years	15	5.49 (0.24)	19	5.53 (0.26)
6-7 years	14	6.34 (0.24)	21	6.35 (0.29)
7-8 years	16	7.48 (0.28)	20	7.45 (0.28)
8-9 years	14	8.42 (0.29)	18	8.46 (0.29)
Total	88	5.94 (1.48)	118	5.89 (1.45)

Table 1. Sample distribution by sex and age

2.2. PROCEDURE

The skill of receiving moving objects was chosen for three reasons: a) because catching moving objects is an interesting task that enables researchers to increase their knowledge on perceptual-motor function (e.g. Mazyn, Lenoir, Montagne and Sabelsbergh, 2007); b) because there are studies that have analysed the evolution of this ability in children aged between 3 and 12 (e.g. Cecchini et al., 2012; Fernández Losa et al., in print); c) because interceptions are regulated using a prospective approach (Peper, Bootsma, Mestre and Bakker, 1994). In this type of approach, the time and place of the interception are not specifically programmed before the movement is executed, rather they result from a continuous adjustment process based on the information specifying the relationship between the receiver and the moving object. This process can be analysed and verbalised by the child and therefore, the researcher is also able to establish a connection between the mental simulation of the movement and its performance.

The 3-9 year age range was chosen since previous studies have found that, during this developmental period, the child succeeds in mastering this skill (Cecchini et al., 2012; Fernández Losa et al., in print). Between the ages of 3 and 5, children have serious problems anticipating the flight of the ball. Until the age of 4, when children are thrown an object, either they do not move or their movements are clearly reactive. Various studies believe that this is due to difficulties in understanding the situation/problem, which involves anticipating a mental representation of their body in a given space during an evolutionary stage in which they are still not capable of associating the visual and topographic information with motor and kinaesthetic elements (Vayer, 1977; Cecchini, Fernández-Losa, 1993, Fernández Losa et al., in print). Furthermore, children do not have sufficient knowledge of the behaviour of moving objects within the space, making it considerably difficult to anticipate their trajectory (Feigelman, 2007). This all hinders the possibility of choosing an adequate motor program and adjusting it moment by moment (Bernstein, 1967). In summary, children have a low level of metacognitive knowledge: declarative, procedural and affective (Dominguez and Espeso, 2002; Ruiz, 1994).

In addressing the analysis of motor imagery, the following were considered: a) the elements to be measured, b) the methodology considered most appropriate for the analysis. As motor imaging is a dynamic state in which an individual mentally reproduces a motor action, two aspects in the resolution of the situation/problem are differentiated between; on the one hand, anticipating the motor programme and, on the other, anticipating the ball’s trajectory. The experimental data suggest that imagined movements are incomplete or not pre-assembled simulations. On the other hand, it appears that the components independent from the imagined movements must be established with respect to the predicted aim of the movement in the same way as real movements are executed (Wolpert, 1997). Based on the data from Cecchini et al. (2012), motor programme anticipation includes the following components: a) visual control; b) adjustment movements to the flight of the ball; c) optimal contact area with the ball; d) cushioning necessary to stop the ball. Anticipating the moving object’s trajectory gathers the following aspects: a) the flight of the ball (drawing); b) time sequence (ordering photographs); place of impact (predicting the impact area using photographs). Indirect means were used to tackle this question, following Piaget’s indications (1985). More specifically, the drawing, gestural indications (reproduced images) and verbal comments through a semi-open interview (anticipated images) was developed by the research team. In the interview, the aim was to ask participants to describe the nature of the images to achieve a better understanding of their typology and components (Guillot and Collet, 2005); in other words, a thought verbalisation method was used (Martini et al., 2004; Lloyd et al., 2006).

The process was as follows. In the first part, the assessor and the child sat facing each other at a table. The assessor posed the following situation/problem to the child: "I am going to stand inside this hoop (pointing to it) and you will stand inside another placed 3 metres away (pointing to it). Do you see this ball? (shows it to the child). I will catch it with my two hands like this (showing the child) and throw it to you underarm so that you catch it with your arms at your chest (demonstrating the position)". The assessor then asked the child if he/she understood and explained what they were going to do. The assessor wanted to know whether the child remembered where they both had to stand (topological space), how the ball would be thrown (reproduced image of the thrower's movement, predicting the trajectory) and how he/she should receive the ball (reproduced image of the catching movement, final aim). The assessor then formulated a series of questions related to the conscious anticipation of a motor programme which includes the necessary adjustments to the flight of the ball: where to look once the ball leaves the thrower's hands; whether the child thinks it necessary to also watch their arms (visual control), which he/she would have to do if the thrower threw the ball too short or long (adjustment movements to the flight); which contact area the child thinks is the most suitable to successfully catch the ball (optimal contact area with the ball); and which cushioning movements are necessary (optimal cushioning). In short, the assessor is trying to determine whether or not the child consciously anticipates the motor programme.

We also wanted to know whether the child anticipates the object's trajectory, its temporal structure and impact area. We therefore asked the child to draw the object's possible trajectory on a photograph featuring both the thrower and receiver; this requires knowledge of the physics of moving objects and of mentally simulating moving images. Five photographs with five different ball trajectories were then shown to the child; one very short, another short, another reaching the receiver, another long and finally, another very long. First the child was asked to order the photographs, from the shortest to longest trajectory, and then indicate which he/she considered appropriate to the distance (perception of trajectories, anticipation of the final destination). To further our knowledge on this ability, we presented the child with another photograph showing the ball's trajectory and five possible points of impact (A, B, C, D, E) at homogenous distances and asked the child to indicate the point where he/she thought the ball would land. 50% of these photographs showed the flight of the ball. Finally, the child was shown five photographs that showed five successive moments of the flight of the ball and was asked to order them according to time sequence, from the moment the ball left the thrower's hands until it reached the receiver (temporal structure).

A static reception test was then carried out with a volleyball ball (65 cm in circumference, 265 g in weight and an inner pressure of 0.3 kg/cm^2) thrown from a distance of 3 meters by an adult who had been previously trained for this purpose. The ball was thrown softy with two hands, with a parabolic up-down trajectory, towards the centre of the hoop were the child was stood. The child had three chances. The whole process was filmed for its subsequent analysis. The study in its entirety had the authorization of the school's headmaster and the student's parents.

2.3. INFORMATION ANALYSIS

For each of the variables indicated, we classified the participants into three levels according to their ability to simulate movements (Piaget, 1985). For those variables measuring motor programme anticipation, the children with the lowest anticipation level, who did not respond, or who did not know or remember what they were asked were grouped in level one; in level two were those children with a vague or limited awareness or who were partially aware of what the assessor posed to them, responding appropriately to some elements but making mistakes in others; and those children who were fully aware of the situation, who understood what the assessor asked and who answered correctly, irrefutably showing their capability of imagining the situation/problem and solving it, were grouped in level 3.

The participants were also classified into three levels for the drawings showing the flight of the ball. In the lowest level were those children who were incapable of drawing any trajectory or who began to draw the trajectory cautiously; the second level included those drawings that connected the thrower to the receiver but were not ballistic; and in the highest level, those drawings showing a suitable and possible parabola for the flight of the ball. In order to group the ability to interpret temporal sequence and anticipate the optimal point of contact in three levels, as two tests were performed in both cases, we classified the participants into three levels: 1, the children performed the two tests incorrectly; 2, they performed one test correctly; 3, they performed both tests correctly.

We used the theoretic model designed by Fernández-Losa et al. (in print) to extract the information about the ball's reception. The model is divided in four phases that occur successively: a) *Flight adjustment phase.* It corresponds to the period in which the object is in the air after leaving the thrower's hands. It includes the overall and segmentary movement of the receiver's body to adapt themselves to the object's speed, trajectory and distance; b) *Contact phase.* It occurs at the very moment when the object makes contact with the receiver. 3) *Cushioning phase*. It corresponds to the moment after contact. Cushioning is understood as the decreasing of the object's inertia force; 4) *Stop phase*. It occurs at the end of the cushioning phase with the controlled detention of the object.

We gave a score of between 0 and 5 to each participant as a way of measuring ability level. If no adjustment movement is made while the object is in flight, we deem the process as over and award 0 points. If adjustment takes place in flight but the ball does not come into contact with the participant, we award 1 point. If there is contact but no cushioning, we award 2 points. If there is cushioning but the ball is not stopped, 3 points. If the object is completely stopped but rests on other parts of the body aside from those indicated, 4 points. If the object is received as intended, 5 points. All observations were simultaneously made by two researchers. For every case, the video was played at normal speed and then in slow motion. When a doubt arose, the video was replayed until both observers reached a decision. The kappa coefficient = 96.4% was used to determine the level of agreement between observers.

In the context of motor learning, Wellman (1937), over sixty years ago, described the evolution of this skill in children, which was subsequently studied by other authors (Caljouw, van der Kamp and Savelsbergh, 2006; Cecchini et al., 2012; Cratty, 1982; Fernández-Losa et al., in print; Mazyn, Lenoir, Montagne and Sabelsbergh, 2007; Meinel Schanabel, 1987; Ruiz, 1987). Based on these previous findings, Fernández-Losa et al. (in print) analysed the stages in the structuring of this skill, reaching the conclusion that they should be grouped into three periods that are consistent with the developmental stages described by Piaget (1985) and Vayer (1977): 3-5 years, 5-7 years, 7-12 years (since a static reception test was analysed in this study, we considered it appropriate to reduce this stage to 7-9 years). The participants were classified into three age groups based on this data (Table 2).

3. RESULTS

3.1. DESCRIPTIVE ANALYSIS

The mean and standard deviation of the variables related to consciously anticipating a motor programme and the object’s trajectory, as well as motor skill levels, are detailed in Table 2.

	MOTOR IMAGERY														MOTOR ACTION	
	Anticipation of the motor programme								Anticipation of the trajectory						Skill	
Age	Visual control		In flight adjustment		Area of contact		Type of cushioning		Flight of the ball		Time sequence		Place of impact			
	M	SD:	M	SD:	M	SD:	M	SD:	M	SD:	M	SD:	M	SD:	M	SD:
3-5	1.74	0.74	1.37	0.68	1.32	0.90	1.96	0.57	1.48	0.69	1.46	0.76	1.29	0.52	1.78	1.69
5-7	2.32	0.69	2.01	0.86	2.46	0.92	1.97	0.52	2.22	0.81	2.59	0.63	1.59	0.70	3.79	1.46
7-9	2.68	0.67	2.64	0.71	2.65	0.71	2.19	0.40	2.90	0.41	2.90	0.36	2.25	0.71	4.55	1.07
TOTAL	2.23	0.78	1.97	0.91	2.15	1.03	2.03	0.52	2.17	0.87	2.32	0.85	1.67	0.75	3.35	1.82

Table 2 Mean and standard deviation of the variables analysed according to age.

The majority of the children, aged between 3 and 5, did not know where to look; 61.3 % thought they should look at their arms. Neither did they consciously anticipate the ball’s trajectory, nor adjust to its possible variations, nor the optimal contact zone. 29.0% did not draw the ball’s possible trajectory and 59.7% drew a straight line at various heights that joined the thrower to the receiver, characteristics in topological space construction. 76.8% were not able to order a temporal structure and 85.5% were unable to correctly predict the place of impact.

The ball reception test found that 69.2% of the children aged 4 did not adjust to the flight of the ball (trajectory and speed); they were only able to catch the ball if it reached them at exactly the optimal contact point. In other words, they did not plan their catching movements based on the speed of the ball and the information of its position. At these ages, the flow of information about the position, speed and temporal information do not combine to give form to the movement of catching. From the age of five, children begin to learn this prospective and continuous system of regulation; the first attempts are limited to stretching out their arms with the intention of adjusting themselves to the flight of the ball. This ability is developed between the ages of 5 and 7. Only 57% anticipated a simulated image of the throw, 29.8% anticipated the ball's parabolic trajectory, and 27.6% still thought it was necessary to look at their arms. The majority did not anticipate consciously adjusting to the movements of the ball during the test; nearly 70% moved their centre of gravity to match their position to the speed and trajectory of the object. During this stage the skill improves significantly.

From the age of 7, children are aware of the situation/problem and of the best way of solving it. They anticipate a simulated image of the object's throwing, the parabolic trajectory and they also solve the problem using thought (anticipated images). All this occurs in the system of regulation which improves significantly.

3.2. MULTIVARIATE ANALYSIS

Based on these results, the MANOVA 2 (sex) x 3 (developmental stage) was carried out; dependent variables were those related to the motor programme's anticipation and the trajectory's anticipation, plus the mean of the total score obtained in the skill test. First the children were grouped into three age groups according to Piaget's proposals (2-7 years, pre-operational stage) to explain intelligence development and how they coincide with the phases in the body diagram structure: 3-5 years, 5-7 years, 7-9 years (Vayer, 1977; Fernández-Losa et al., in print). The notion of covariance homogeneity was then studied using the Box M test. The result revealed no resolution (Box M = 262.36 F = 1.36, $p < 0.001$). As a result, we followed the suggestions of Olson (1979) and Tabachnick and Fidell (1996) to use the Pillai's Trace, instead of the Wilks lambda, to assess the multivariant significance of the main effects and interactions. The MANOVA gave a significant main effect for developmental stages: Pillai's Trace = 0.84, $F_{(20, 362)} = 13.17$, $p < 0.001$, $\eta^2 = 0.42$; but not for sex: Pillai's Trace = 0.04, $F_{(10, 180)} = 0.87$, $p < 0.1$, $\eta^2 = 0.04$. Subsequent univariate ANOVAs revealed statistically significant differences for the developmental stages in all the variables. We obtained the following results: *visual control* [$F_{(1, 189)} = 29.24$, $p < 0.001$, $\eta^2 = 0.23$], *adjustment movements to the flight of the ball* [$F_{(1, 189)} = 40.47$, $p < 0.001$, $\eta^2 = 0.30$], *optimal contact zone with the ball* [$F_{(1, 189)} = 40.57$, $p < 0.001$, $\eta^2 = 0.30$], *cushioning required to stop the ball* [$F_{(1, 189)} = 4.74$, $p < 0.05$, $\eta^2 = 0.05$], *flight of the ball* [$F_{(1, 189)} = 59.64$, $p < 0.001$, $\eta^2 = 0.39$], *time sequence* [$F_{(1, 189)} = 85.01$, $p < 0.001$, $\eta^2 = 0.16$], *impact point* [$F_{(1, 189)} = 27.37$, $p < 0.001$, $\eta^2 = 0.22$], *motor skill* [$F_{(1, 189)} = 55.97$, $p < 0.001$, $\eta^2 = 0.37$].

Post hoc tests were performed using Tukey's HSD for comparisons in pairs between each age section. Significant differences were seen in all the variables between each developmental stage ($p < 0.001$), except in *cushioning to stop the ball* where no differences were found between the first and second developmental stages, but were between these two stages and the third, and in the *optimal contact zone* in which no differences were observed between the second and third stages, but differences were observed between these and the first.

3.3. STRUCTURAL EQUATION ANALYSIS

A structural analysis was performed in order to analyse how awareness or motor imagery of the elements necessary to solve a motor problem, in this case catching a ball in the arms while standing still, influences skill levels in children aged between 3 and 9. A unique factor measuring mental representation of the movement or motor imagery and which gathers the variables included in the anticipation of the ball's flight and the motor programme is proposed in the model. We believe that they are two aspects of one unique process, the conscious regulation of the action. Motor skill levels gather in one unique factor the results obtained in each of the tests. Finally, the aforementioned developmental stage variable was included.

Based on the data from Caeyenberghs et al. (2009), in this study the hypothesis was put forward that the child through his/her development progressively introduces more complicated relationships between the elements; this could represent how, in turn, they impact on motor skill levels to the extent that awareness takes control. In other words, childhood developmental stages which are successively related to skill levels predict awareness.

Following the two-step procedure recommended by Anderson and Gerbing (1998), the measure of construct validity was analysed first through a confirmatory factor analysis. A structural, theoretical or causal model was then predicted which enabled information to be obtained on the predictive relationships between the analysed variables. Next the mediator role of motor imagery in the relationship between developmental stages and motor execution were examined. Finally, we confirmed an alternative model in which developmental stages predict motor skill which successively predicts motor imagery. If this was confirmed, motor images would be a consequence of the skill previously elaborated at a practical level (unconsciously).

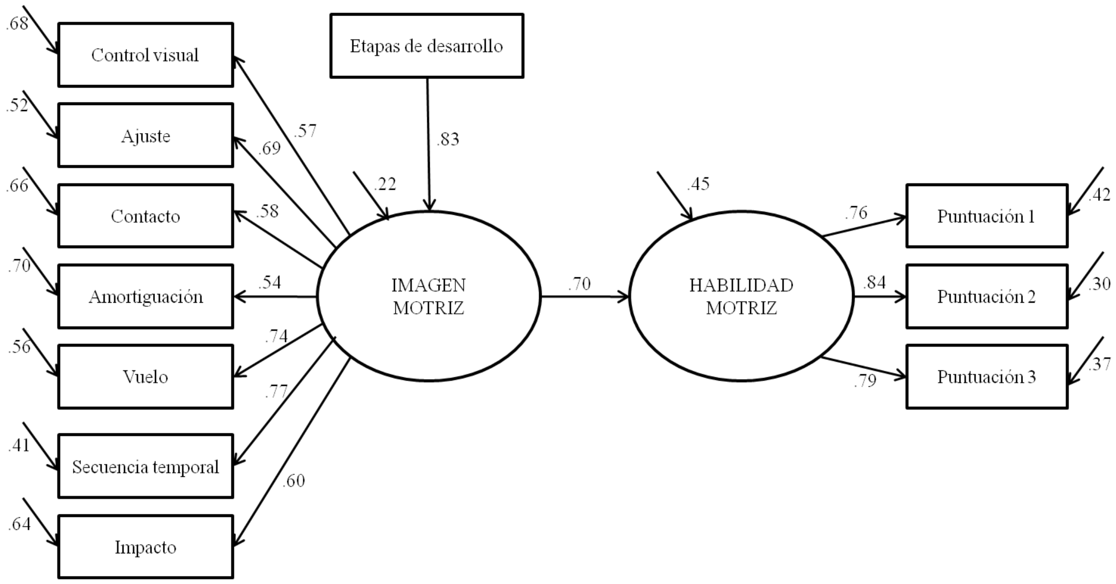
This method assumes multivariate normality. Preliminary analyses showed that some variables observed were not normally distributed. Results also showed that the standardised estimation of Mardia's coefficient was relatively large (multivariate kurtosis = 12.33). For this reason an analysis was carried out based on the use of the Satorra Bentler χ^2 statistic (S-Bχ^2; Satorra and Bentler, 1998) and the use of the standard robust estimators implemented in the

EQS 6.2 statistical software, in place of the usual MLχ^2 statistic, since it serves as a correction for χ^2 when the distribution assumptions are broken.

In each of the models described above, the evaluation of the data's goodness-of-fit is determined based on multiple criteria (Byrne, 2008): for increasing adjustment rates, *CFI (Comparative Fit Index) was used, and RMSEA (Root Mean Square Error Approximation) and SRMR (Root Mean Square Residual) were used as a measurement of absolute adjustment indices, determining the level at which the model predicts the covariance matrix. *CFI is the robust version of CFI which is calculated based on the S-Bχ^2 statistic; Hu and Bentler (1999) suggest a value of 0.95 as indicative of good adjustment. *RMSEA is the robust version of RMSEA and takes into account approximation error in the population. This discrepancy is expressed by the degree of freedom and is therefore sensitive to the model's complexity; values lower than 0.05 indicate good adjustment and values as high as 0.08 represent reasonable approximation errors. A 90 % confidence level, supplied by *RMSEA (Steiger, 1990), was included to complete the analysis. Finally, an SRMR value below 0.08 indicates good adjustment (Hu and Bentler, 1999).

We then proceeded to check the construct validity to the measurement model used (Anderson and Gerbing, 1988). Adjustment rates showed that the model's hypothesis was well adjusted to the data; S-Bχ^2 (42) = 47.72, p = 0.252, *CFI = 0.99, SRMR = 0.04, *RMSEA (90% CI) = 0.26 (0.000-0.057). Secondly, the structural model was estimated and the hypothesis had a well formed a structure: S-Bχ^2 (43) = 48.01, p = 272; *CFI = 0.99, SRMR = 0.04, *RMSEA (90% CI) = 0.24 (0.000-0.056). All the parameters calculated were significant and are shown in Figure 1. The developmental stages positively predicted the motor image (B = 0.83), which subsequently predicted the motor skill (B = 0.75).

To examine whether motor imagery interferes with the influence of developmental stages on motor skill, the four steps proposed by Baron and Kenny (1986) were followed. The first step establishes whether the independent variable predicts the mediator. As shown in Figure 1, the developmental stages significantly predict awareness. The second step establishes whether the independent variable predicts the outcome of the dependent variable. A model in which the developmental stages were directly linked to motor skill was tested to examine this prediction. The steps from the developmental stages to awareness and from awareness to motor skill were reduced to zero. The direct step was B = 0.63 and was significant. The third step shows that the mediator predicts the outcome of the dependent variable while controlling for the independent variable. As shown in Figure 1, awareness was a significant predictor of motor skill after the control exercised by the developmental stages.



Control visual	Visual control
Ajuste	adjustment
Contacto	contact
Amortiguación	cushioning
Vuelo	flight
Secuencia temporal	time sequence
Impacto	impact
Etapas de desarrollo	developmental stages
Imagen motriz	Motor imagery
Habilidad motriz	Motor skill
Puntuación	Score

Figure 1. The hypothesis model formulated between developmental stages, awareness and motor skill. The rectangles represent observed variables and the circles, latent variables.

The final step, carried out using the same model as Step 3, examines whether in the presence of a mediator, the direct path from the independent variable to the dependent variable is reduced to zero (for example, complete mediation), or whether it is reduced in size but not to zero (for example, partial mediation). In Figure 1, a direct path is added from the developmental stages to motor skill; this path was $B = 0.05$, not significant, and considerably smaller than the original $B = 0.63$ path. The adjusted Wald interval suggested that the elimination of this path would not damage the model's form. Consequently, it was concluded that awareness almost entirely influences the effect of the developmental stages on motor skill.

Finally, we confirmed an alternative model in which developmental stages predict motor skill which successively predicts motor imagery. Adjustment rates showed that the model's hypothesis was well adjusted to the data; S-Bχ^2 (43) = 98.86, p = 0.001, *CFI = 0.91, SRMR = 0.09, *RMSEA (90% CI) = 0.92 (0.072-0.113).

The evolution of motor imagery and motor skill according to the developmental stages, having converted the factors into z-score, are shown in Figure 2.

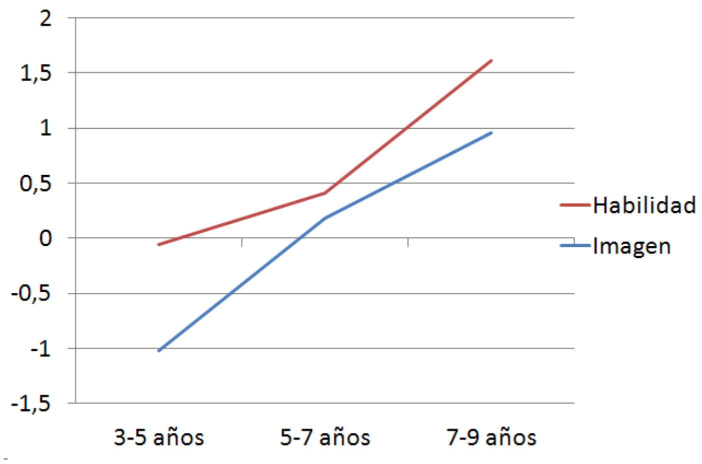


Figure 2. Evolution of motor imagery and motor skill.

Habilidad	ability
Imagen	imagery
Años	years

4. CONCLUSIONS AND DISCUSSION

The purpose of this study is to analyse how awareness or motor imagery of the elements necessary to solve a motor problem, in this case statically catching a ball in the arms, influence skill levels in children aged between 3 and 9.

The results of this study show how the stages in the structure of the body diagram described by Vayer (1997) and validated to explain the evolution of learning this skill (receiving moving objects) by Fernández et al. (in print), also explain the changes in awareness of the elements involved in the resolution of this situation/problem. Univariate analyses revealed statistically significant differences in all the variables.

These results are consistent with those observed in other studies which show how the accuracy of the imagined movement improves constantly during childhood, and that this ability is associated with the actions of planning and control (Bouwien et al., in print; Lloyd et al., 2006; Martini et al., 2004). They are also consistent with the studies indicating that images and motor praxis are subject to the same environmental and physiological limitations (Decety and Jeannerod, 1996; Jeannerod, 2001; Maruff et al. 1999), and with the findings of Courtine et al. (2004).

In summary, these results suggest that changes occur in child development, in the ability to mentally solve problems arising from catching moving objects, which are parallel to changes in the ability to solve the same problem in real-life practice. What is the nature of these changes? In this study the hypothesis was put forward that the child, through his/her development, progressively introduces more complicated relationships between the elements which could represent how, in turn, they impact on motor skill levels to the extent that awareness takes control. In other words, that child development stages predict motor imagery or the capacity to mentally anticipate a solution to the problem that is successively related to skill levels. Structural equation analysis enables the acceptance of this hypothesis. In fact, the direct effect of these developmental stages substantially reduced when awareness or motor imagery was introduced in the model, confirming the mediator role of the last construct in the link between the two independent variables. These results are consistent with those observed by Caeyenberghs et al. (2009), and explain how improvements in skill levels, originating in the child as a result of maturing or learning, are conditioned by awareness, not only of the objective and of the results of the problem posed, but also as a result of the means necessary to solve it. We also confirmed an alternative model in which developmental stages predict motor skill which successively predicts motor imagery. Adjustment rates showed that this model’s hypothesis did not adjust to the results, for which reason it should be rejected.

These results are also consistent with neural studies on mental representation, which have consistently found that activation patterns are common both to mental movement simulation and to the actual generation of the movement. The hypothesis that neurocognitive networks are the same for both real movements and simulations could explain these results (Fourkas et al., 2008; Kasess et al., 2008; Ramnani, 2006; Stinear et al., 2007).

Therefore, in order to intervene in this environment, in addition to understanding the situation/problem, it is necessary to elaborate a motor programme that includes regulation and control systems and that takes into account the elements to be accommodated, in this particular case anticipating the trajectory and impact or contact point. Having undertaken the action, we inspected its execution and controlled the children’s behaviour so that it was appropriate to this programme. Finally, we verified their conscious activity, comparing the effects of their actions with their original intentions, correcting any error made (Luria, 1984). Normally a child that does not perform the task correctly does not have meta-knowledge since he/she does not put into action their understanding and strategies (Dominguez and Espeso, 2002).

Cecchini et al. (2012) analysed the transfer process in the learning of motor skills, reaching the conclusion that the regulating system is transferred, fundamentally visually and kinaesthetically, as opposed to serial movements. On this basis, they suggested that the teacher present his pupils with varied and open proposals, in changing situations, so that the comparison between real and ideal movement parameters comes into play. These authors also observed more parallel than series learning; therefore as well as varying the tasks, they must be presented globally.

Based on the results of this research, the child must be aware of the situation/problem and progressively, of the motor programme and the elements involved in the activity, since they predict success. To do so, situations/problems should be posed using the teaching strategy of guided discovery; this leads to reflection about the causes of the errors and the best way of eliminating them. The complicated relationships between genetics and environment, between culture and upbringing continue to play a very significant role in child motor development (Ruiz and Graupera, 2003).

This study has some limitations related to the difficulty in measuring motor imagery in children at these ages and extrapolating these observations to other contexts or skills. There is a significant limitation in the design of the cross-sectional study used; therefore longitudinal studies should be carried out that show the time sequence of the phenomena analysed. New studies should also be carried out on the relationship between awareness and learning other skills. Finally, there should also be research measuring the incidence of teaching based on mental representation of a motor skill to determine their results at these ages.

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