Journal of Physical Education and Sport ® (JPES), 18(3), Art 242, pp. 1654 - 1660, 2018
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Children's knowledge of skill cues and the enhancements of motor skill performance

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Published online: September 30, 2018
(Accepted for publication August 10, 2018)
DOI:10.7752/jpes.2018.03242

Abstract:
Problem Statement: Motor learning research has showing direct experimental evidence of important cognitive and motivational roles of instructional strategies on the acquisition of motor skills. However is empirical evidence of a positive relationship between children's knowledge of fundamental motor skill cues and their accompanying motor skill performance. Approach: The present study extended previous researches by using of the TGMD-2 as a dependent measure to address cognitive understanding of children relative to motor performance motor skill learning, but also the way such information is put available. Purpose: The objective of this study was to examine the relationship between children's ability to verbally recall skill specific cues and their motor skill performance. Methods: Forty-six children with developmental delay from 27 urban public schools in southern Brazil completed the Test of Gross Motor Development-2 as well as a verbal recall checklist based upon the TGMD-2 skill components. Logistic regression was used. Results: the logistic regression showed that motor performance was positively and significantly related to verbal recall for running, gallop, hop, leap, jump, slide, catch, throw, and rolling skills. Indeed, children who could state the cues for various skills were up to 2-to-17 times more likely to have mastered their skills. Conclusions: The current findings support the notion that cue words are related to and predictive of motor skill acquisition for many fundamental motor skills. Instruction is critical to learning these skills, and that incorporating instructional strategies such as cue words can influence how well the skills are learned.
Key words: intervention study, child behavior, motor skills, motor activity, motor disorders, verbal recall.

Introduction

Gross motor skill proficiency is critically important with respect to engage in developmentally appropriate play activities (Bar-Haim & Bart, 2006), facilitate the learning of more complex motor skills, and use the skills in games (Seefeldt & Haubenstricker, 1982). Furthermore, motor proficiency in object control skills in primary school years has a strong influence on subsequent fitness during adolescence years (Barnett, Beurden, Morgan, Brooks, & Beard, 2009). Despite this assertion, many children fail to advance in their gross motor skills and ultimately demonstrate developmental delays (Sugden, 2007). Such children often demonstrate low frequency of play engagement, spend more time as onlookers and less time playing (Bar-Haim & Bart, 2006; Kennedy-Behr, Rodger & Mickan, 2011), as well as exhibit high frequency of solitary-functional play behavior (Bar-Haim & Bart, 2006), relative to children presenting typical motor development.

In the last years, two major systematic reviews have showed the interventions effectiveness in changing children' performance over time (Logan, Robinson, Wilson & Lucas, 2012; Riethmuller, Jones & Okely, 2009). In particular, research investigating mastery climates (Valentini, Pierosan, Rudisill & Hastie, 2016; Valentini, Rudisill & Goodway, 1999a, 1999b) and play (Bar-Haim & Bart, 2006; Bjorklund & Brown, 1998; Pellegrini & Smith, 1998) has emphasized the importance of cognitive engagement in learning, particularly the use of verbal cues and self-monitoring. Self-monitoring has been considered an essential tool for less experienced learners (Weiss & Giel, 2005), and a key strategy for children with motor difficulties (Mandich, Polatajko, Missiuna & Miller, 2001; Sugden, 2007). A intervention study, for example, suggested that implemented self –monitoring strategies using modeling and cue words in a mastery climate was more effective in change children motor performance over time as compared with a climate (exercise play) that did not focus on those strategies (Valentini, Pierosan, Rudisill & Hastie, 2016).

In terms of assisting children to learn motor skills, research has shown that implementing instructional strategies increases the likelihood that gross motor skills will be learned (Martin, Rudisill, & Hastie, 2009; Robinson & Goodway, 2013; Robinson, Rudisill & Goodway, 2013; Valentini, Pierosan, Rudisill & Hastie, 2016; Valentini & Rudisill, 2004a, 2004b). Motor learning research has showing direct experimental evidence of important cognitive and motivational roles of certain instructional strategies on the acquisition of motor skills.

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For instance, children learned skills better when they were taught the basic components of the skills through the use of video modeling and verbal and visual cues compared to conditions where the cues were not used (Janelle, Champenoy, Coobes, & Mousseau, 2003). Autonomy over the provision of instructional modeling was observed to enhance positive affect, perceived competence and the learning of a ballet sequential task relative to a condition where children were not allowed to control when to observe the video model (Lemos, Wulf, Lewthwaite, & Chiviacowsky, 2017).

Furthermore, children provided with verbal cues about interactions between components showed learning gains on the Front-Crawl swimming stroke compared with children who received instructions about individual skill components (Marques-Dahi, Bastos, Arauhjo, Walter & Freudenheim, 2016). Also, verbal cues inducing an external focus (on the movement effects) instead of an internal focus (on the body parts) or no attentional focus induction (control participants) have demonstrated to benefit the acquisition of motor skills in children learning the tennis forehand striking skill (Hadler, Wulf, Schild, & Chiviacowsky 2014), the vertical jump with half turn from gymnastic, (Abdollahipour, Wulf, Psotta & Nietto, 2015), dynamic balance tasks involving riding a pedalo (Flôres, Schild, Chiviacowsky, 2015) and the ballet pirouette (Silva, Lessa, & Chiviacowsky, 2016), as well as rolling balls to a target in bowling (Abdollahipour, Nieto, Psotta, & Wulf, 2017).

What is still missing is empirical evidence of a positive relationship between children's knowledge of fundamental motor skill cues and their accompanying motor skill performance. The present study extended previous researches by using of the TGMD-2 as a dependent measure to address cognitive understanding of children relative to motor performance motor skill learning, but also the way such information is put available. The purpose of this study was to determine the extent to which children exhibiting motor delay do (or do not) know the cues to various locomotor and object control skills are able to successfully execute those skills. It was predicted that those children who can describe the cues associated with motor skills would be more likely to successfully execute the skills.

Materials and Methods

Participants and home-school context

The participants in this study were recruited through media announcements and meetings with the local board of education, teachers, and parents in a large urban city in southern Brazil. Children (n=138) from 27 urban public schools were indicated to participate in the study and were assessed using the Test of Gross Motor Development - TGMD-2 (Ulrich 2000). Children demonstrate motor delay with performance scored ≤ 5^{th} percentile on TGMD-2 (Ulrich, 2000) and, the capability to perceive and comprehend instructions, norms and school protocols were eligible for the present study. Participate in the present study 46 children demonstrating motor developmental delay (28 boys and 18 girls), aged 4.0 to 9.0 years (M = 7.95, SD = 1.3). All participants demonstrated motor delays, but none of the children have disability as was informed by the family' pediatrician. None of the children previously participated in any compensatory or youth sport program. The ethno-racial characteristics composition of the groups of children were 65% white, 25% black, 8 % *Pardos*, 2 % not reported by parents. The ethno-racial information was reported by parents, according to the categorization of color and race used by Brazilian government (IBGE, 2015). Parental signed the informed consent and participants verbally agree to participate in the present study.

All children were from low-income families, living in periphery regions of a major city in the south of Brazil, and were enrolled in state public schools nearby their homes. Children walked to school alone or with older siblings and friends. The schools have limited physical space and equipment. Physical education lessons were provided two times per week with 45 minutes each lesson. Classrooms teachers conducted the lessons, in the state' public schools was not mandatory to have a physical education teacher. The physical education lessons occur in wasteland nearby the schools, at the schoolyard or small or open sports court; also, two schools used occasionally the cafeteria for classes. To further describe the motor lessons opportunities offered for children, five physical education lessons for each child were observed. The main content of the lessons was free games, with boys usually choose soccer and girls choosing tag games, dance in small groups and dodge ball. Board games were also an option in the raining days since none of the schools have appropriate gym. Teachers provided directions to play, organize the games and rules but specifically motor skills instruction were not provided. All classroom teacher reported have few equipment and lack of training to teach physical education.

Instruments

Motor skills. To assess motor skill performance, the Test of Gross Motor Development second edition TGMD-2 (Ulrich, 2000), validated for Brazilian children (Valentini, 2012), was used. The 12-item test included 6 locomotor skills (run, leap, gallop, hop, jump, and slide) and 6 object control skills (catch, strike, bounce, underhand roll, overhand throw, and kick). Test administration took approximately 20 to 30 minutes per child; was conducted at the university campus and was video recorded for further scoring. Two independent raters (doctoral students with three years of TGMD-2 training) rated the children's performances following test protocol the components of each skill were scored as present ("1") or absent ("0") and raw scores were obtained for each subtest. Inter-rater reliability was high (locomotor subtest: ICC = .91; object control subtest: ICC = .88) and the results were compatible with the coefficient reported by Ulrich (2000). Similar with the protocol of Cliff, Okely, and Magarey (2011), for each skill, a child was classified as exhibiting mastery (i.e., exhibiting all or all but one component) or low motor performance skill (two or more components absent).

Verbal recall. Cue words' assessment was conducted based in a previous published protocol (Valentini, Pierosan, Rudisill & Hastie, 2016). The authors conducted a task-analysis of each TGMD-2 (Ulrich's (2000) skill and provided a set of short and age appropriate cue words that described the single motor criteria of the movement. A score sheet consisting of a TGMD-2 line drawing illustrating each skill, the specific performance criteria for each skill, and several verbal cues that described the motor criteria were used (Valentini, Pierosan, Rudisill & Hastie, 2016). Table 1 presents sample verbal cues for each skill used in the children' assessment.

Table 1. Cue Words for Each Skill Used During the Intervention

Skill	Cues
Locomotor	
Gallop	One foot front, arms bent waste level, gallop-gallop
Hop	Look at, bend one leg, bend arms, incline trunk, hop-hop
Jump	Look at, bend knees, arms back, jump, arms reach
Leap	Run, one foot takeoff, flow, land on other foot
Run	Move arms and legs, off the floor, feet near mid-line
Slide	Turn to the side, arms bend waste level, slide-slide
Object control	
Catch	Ready hands-soft fingers, eyes on the ball, reach-catch, bend arms
Dribble	One hand, push with fingers, near foot, waste level
Kick	Look at the target, look the ball, one step near the ball, kick
Roll	One foot in front, incline trunk, ball back, look the target, release the ball
Strike	Side to the target, arms back, look, one step, strike
Throw	Ball back, point to the target, one step, throw

During testing, the children were interviewed and asked to verbally describe the motor skills included on the TGMD-2. This interview (which was video recorded) occurred after the instructor modeled the skills and the participant completed one trial of each skill. Some questions were systematically used throughout all the interviews with the participants. For example, participants were first asked to perform the skill, "Can you show me the best way to strike a ball?" After the participant completed the actual trial the child was asked, "Can you use words to describe how to strike a ball, without demonstrating the skill?" If the child response was "yes" or "no" the researcher to encouraged him/her to provided more information. This procedure was used for all the skills. Each child physically performed each skill and then verbally described it.

The scoring system required a dichotomous choice for each performance criteria, scored as either "described" or "not described" by the children. A point was credited each time the children adequately described the criteria. The range of verbal recall scores for each skill was variable depending upon the number of motor criteria (0 to 3 for run, slide and gallop; 0 to 4 for leap, bounce, catch, overhand throwing, and kicking; 0 to 5 for hop, jump, strike and roll). Two independent raters, with 3 years of experience in task analyses, scored the children's verbal description of the skills. Inter-rater reliability was high (.96) between the raters.

Motor skill intervention design

A motor skill intervention program, based in previous literature (Valentini, Pierosan, Rudisill & Hastie, 2016; Valentini & Rudisill, 2004a, 2004b; Valentini, Rudisill & Goodway, 1999a, 1999b) was provided for all participants. Strategies consistent within the six TARGET structures (Task, Authority, Recognition, Grouping, Evaluation, and Time) emphasizing the practice of fundamental motor skills were implemented. Developmentally appropriate activities were implemented to challenge and accommodate a wide range of skill children' levels of motor proficiency.

Regarding the "Task Structure" a variety of motor tasks were implemented in stations covering 7 to 10 stations every lesson, in order to have a small number of children play in each station an great opportunity for practice. Novelty and different levels of difficulty were inbuilt within these tasks to accommodate children variety of motor performance. A great variety of equipment, to encourage children to keep engage, was provided in each station (Valentini, Rudisill & Goodway, 1999a, 1999b). Children were allowed to move autonomously from the station to station according to their interests in the motor tasks, but only for stations not busy. Whenever was necessary teacher directed the children to the next available station. Instruction and modeling paired with cues words were provided in every lesson.

Regarding "Authority Structure" children have autonomy to choose different levels of task difficulty within the stations. The children also have the choice to move to stations and stay practice a specific skill as much as felt needed. For the “Recognition Structure” positive encouragement, reinforcement and individual praise based on personal accomplishments was provided for each child over the intervention period (Valentini, Rudisill and Goodway, 1999a, 1999b). Opportunities to choose peers, practice in heterogeneous small groups, and work towards respecting differences and helping each other were promoted in the “Grouping Structure” (Valentini, Rudisill & Goodway, 1999a, 1999b).

Regarding to “Evaluation Structure” individual and group evaluation related to participation and positive behavior was provided. Children were stimulated to use the verbal cues teach in the beginning of each lesson during practice (Valentini, Rudisill & Goodway, 1999a, 1999b). “Time Structure” was implemented by allowing children to self pace and tailor their own practice in the stations. The number of stations provided for children and the skills content in each station was based taking in consideration the initial level of children performance, assessed by the TGMD-2.

Procedures

The university ethical committee approved the study. The study was announced in the local newspaper and network. Parents contact the research and attended to a meeting at the university. Parental consent form and participants agreement were obtained for all participants. Children participate in an intervention focus on fundamental motor skills. Two intervention groups were formed, attending to intervention on different days, to have an adequate ratio teacher/children.

The intervention was conducted at the university campus and all children participated in a 14-week-intervention (28 sessions/2 times per week for 1 hour). All lessons were video recorded. A physical education teacher, with more than five years of teaching experience was responsible for the delivery the interventions. The set of specific verbal cues were introduced to the children during the intervention lessons. The teacher opens the lessons presenting the learning objectives for the day. During this introductory period (8 minutes), across all lessons, and each time a new skill was introduced, children received instruction about the stations and observed the skills being modeled, by the teacher or a peer (Lemos et al., 2017). The modeled skill was paired with cue words (simple verbal descriptions) that describe shortly the motor criteria required for each skill. During the introductory period teacher also presented the motor tasks, the equipment and teach children how to use it. During the next 45 minutes the children practice at the stations and were positively reinforcement to keep engaged. Children were instructed to use the verbal cues during motor practice by the teacher. Every lesson, at the end of motor practice (seven minutes) teacher used group’ gathering strategies to reinforce adequate behavior, program’ rules, and the content learned that day. At this moments teacher also praised children for affords as well as peer cooperation and respect.

By the end of the intervention period, trained professionals at the university campus individually assessed children regarding to motor performance and verbal recall.

Data analysis

Correlations between the each motor skills score and verbal recall was calculated. For each of the OC and LOC skills, a chi-square test of independence was calculated to determine if a relationship existed between knowledge of cues (a continuous measure) and skill mastery (dichotomized as either yes or no). Separate binomial logistic regression were conducted for each skill to predict the odds ratio that students would achieve skill mastery, using the formula: logit(y) ~ intercept + slope * (number of cues)

Results

Positive, moderate, and significant correlation between motor and verbal recall scores were found for all locomotor skills (run: r = .33, p = .011; gallop: r = .45, p = .001; slide: r = .46, p = .001; hop: r = .35 p = .009: jump: r = .36, p = .006; leap: r = .30, p = .022) and for five object control skills (bounce: r = .33, p = .012; catch: r = .49, p =.001; throw: r = .55, p = .001; roll: r = .47, p = .001; kick r = .30, p = .045), and non-significant for strike (r = .04, p = .814)

Table 2 contains Nagelkerke R^2 values that provide the explained variance of each skill. The logistic regression model was statistically significant for all locomotor skills (run: χ^2 (1) = 9.37, p = .002; gallop: $\chi^2(1)$ = 14, p < .000; slide: $\chi^2(1)$ = 14, p < .000; hop: $\chi^2(1)$ = 6.02, p =.014: jump: $\chi^2(1)$ = 7.46, p = .006; leap: $\chi^2(1)$ = 6.05, p = .014). The explained variance based on the model was higher for gallop and slide (40%) and lower for hop, leap and jump (around 20%). The model correctly classified near 70% -to-80.4% of cases.

The logistic regression model was statistically significant for four object control skills (bounce: $\chi^2(1)$ = 6.52, p = .011; catch: $\chi^2(1)$ = 7.28, p = .007; throw: $\chi^2(1)$ = 14.42, p = .001; roll: $\chi^2(1)$ = 9.75, p = .002), and non-significant for strike ($\chi^2(1)$ = 3.69, p = .055) and kick ($\chi^2(1)$ = .95, p = .330). The explained variance based on the model was higher for throw (37%) whereas for kick (3%), almost no variation could be explained by the use of verbal cues. The model correctly classified near 70% to 74% of the cases.

Table 2 also shows the results of the binomial logistic regression to categorization prediction. We estimated the probability motor performance could be correctly classified (i.e., predicted) from the use of verbal cues for each skill, assessing the effectiveness of the predicted classification against the actual classification. The number of the mastery and low motor proficiency cases that where correctly predicted by the use of cue words (sensitivity predicted by the model) was high. For example, example 37 children who knew the verbal cues for running mastered the skill and 36 children who knew the verbal cues for strike also mastered the skill. The unfit number of cases is also provided. For example, for hop, five children knew the verbal cues but performed poorly while six children performed at the mastery level yet did not know the cues. The overall percentage accuracy in overall classification, which reflects the percentage of cases that were correctly classified, was near 70% or above for the majority of skill (run and gallop around 80%). That is, increasing the use of verbal cues was associated with an increased likelihood of exhibiting mastery performance and overall verbal cues were stronger predictors for motor performance in each skill.

Table 2. Nagelkerke R^2 Values, Correct Fit and Unfit Cases & Overall Model Corrected Percentage for Each Skill

Skills	Nagelkerke R^2	Fit Cases Predicted (*N*) Mastery & Cues Knowledge	Fit Cases Predicted (*N*) LMP & Lack Cues knowledge	Unfit Cases Predicted (*N*) Mastery & Lack Cues knowledge	Unfit Cases Predicted (*N*) LMP & Cues Knowledge	Overall Model Correct %
Run	.29	37	-	-	9	80.4
Gallop	.40	36	-	-	10	78.3
Hop	.17	11	24	6	5	76.1
Leap	.19	36	0	-	10	78.3
Jump	.20	14	17	10	5	67.4
Slide	.40	36	0	-	10	78.3
Strike	.11	34	0	-	12	73.9
Dribble	.19	32	0	-	14	69.6
Catch	.20	7	25	11	3	69.6
Kick	.03	30	0	-	16	65.2
Throw	.37	25	7	6	8	69.6
Roll	.28	28	4	6	8	69.6

Table 3 provides the results for the Wald test, beta values and expected beta. The Wald test was used to determine statistical significance for each skill. From these results it can be seen that all locomotor skills and three object control skill (catch, throw and roll) added significantly to the model, but strike, bounce and kick (*p* values .973, .999 & .337) did not. The data in the Table 2 show the probability of an event occurring based on a one-unit change in an independent variable. For example, the table shows that the odds of mastering the gallop or the slide are 17.17 times greater if the child knows the verbal cues for those skills. For other significant skills the odds range from near 2 to 5 times greater.

Table 3. Wald Test Results, Beta Values and Expected Beta Value and C.I.

	Beta	Wald	Sig	Exp. Beta	95% C.I. Exp. Beta Lower	95% C.I. Exp. Beta Upper
Run	1.56	5.57	.018	4.75	1.30	17.35
Gallop	2.84	6.80	.009	17.17	2.03	145.52
Hop	.97	5.22	.002	2.64	1.15	6.06
Leap	1.06	4.72	.030	2.89	1.11	7.53
Jump	.68	6.49	.011	1.97	1.17	3.31
Slide	2.83	6.80	.009	17.17	2.03	145.52
Strike	.50	3.22	.073	1.65	.95	2.86
Dribble	16.65	0.00	.999	3.41	0	-
Catch	.63	5.70	.017	1.88	1.12	3.16
Kick	.50	.92	.337	1.65	5.93	4.59
Throw	1.02	9.11	.003	2.78	1.43	5.41
Roll	1.15	6.43	.011	3.16	1.30	7.69

Discussion

The purpose of this study was to determine the relationship between the knowledge of motor skill (locomotor and object control included on the TGMD-2) instructional cues and the ability to execute those skills by children with developmental motor delays. The hypothesis that children who were knowledgeable about the cues for a skill would be more successful in executing the skill was supported with respect to the locomotor skills, and partially supported for object control skills. More specifically, the results showed that a strong relationship exists between knowledge of cues and skill mastery for all locomotor skills and for four object control skills (catch, bounce, throw, roll), suggesting that motor skills performance can be predicted based on the knowledge of cues for these skills. The results indicate that children with motor delays are far more likely to demonstrate mastery of the skills if they know the cues associated with the gallop, slide, run, hop, leap, jump, bounce, catch, throw and roll. Interestingly, having knowledge of the cues for certain skills, such as the gallop, slide, and throw was even more predictive of mastery skill performance than the other locomotor and object control skills.

These results are supportive of earlier research that has shown that cognitive strategies are effective in improving the motor performance of young children in the early phases of motor skill acquisition (Hastie, Rudisill & Wadsworth, 2011; Martin, Rudisill, & Hastie, 2009; Valentini, Pierosan, Rudisill & Hastie, 2016; Valentini & Rudisill, 2004a, 2004b). Researchers also suggest that cue words reinforce memory and improve recall for motor skill learning (Valentini & Rudisill, 2004a, 2004b). Furthermore, intervention studies suggested that the lack of use of cognitive strategies prevent children to positively change their motor performance (Logan et al 2012; Valentini, Pierosan, Rudisill & Hastie, 2016). However, we must acknowledge that the strength of the relationships varies between skills and is not universal for object control skills.

Considering the importance of knowledge of motor skill instructional cues and the ability to execute those skills by children observed in the present study, future research might seek to assess the utility of individual cue words (e.g., Abdollahipour et al., Hadler et al., 2014; Palmer, Matsuyama, Irwin, Porter, & Robinson, 2017), or the learners' autonomy in choosing when to receive instructional cues (e.g., Lemos et al., 2017), particularly in light of the findings showing the "benefit or harm" of adopting certain instructional strategies in this population.

Conclusions

The current findings support the notion that cue words are related to and predictive of motor skill acquisition for many fundamental motor skills. The knowledge of motor skill verbal cues is a viable and effective instructional strategy for motor skill learning (Valentini, 2004a, Weiss & Giel, 2005) and should be utilized by practitioners, particularly with children who are demonstrating motor delays. Fundamental motor skills are the foundation of children's movement and play. Research suggests that instruction is critical to learning these skills, and that incorporating instructional strategies such as cue words can influence how well the skills are learned. Practitioners, teachers and therapists, should strongly consider incorporating cue words into their instruction to promote learning these critically important skills.

Acknowledgement: this work has been support financially by the CAPES and CNPq.

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