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The Effect of Increasing Cognitive Load of Rhythmic Games on Theory of Mind in Children with Developmental Coordination Disorder

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ABSTRACT

Background: The purpose of the present study was to determine the effect of increasing cognitive load of rhythmic games on theory of mind in children with developmental coordination disorder.
Methods: This is a quasi-experimental research. Participants in this study were 25 children (9 boys and 16 girls) aged 8 to 10 years old who were screened based on Parental Developmental Coordination Disorder Questionnaire (DCD- Q07) and confirmed for their impairment using the Movement Assessment Battery for Children (MABC) Test. All participants underwent Raven's test in the same condition and students with normal intelligence entered the study. Participants were matched in two groups of experimental (n=13) and control (n=12). The experimental group performed rhythmic games with cognitive load for 8 weeks and 2 sessions of 45 minutes per week, but the control group received only rhythmic games intervention. Participants were assessed before and after the intervention by Steerneman theory of mind test. Statistical analysis was performed using univariate and multivariate covariance tests.
Results: The results indicated that rhythmic games with cognitive load developed the theory of mind in children with developmental coordination disorder (P=0.01).
Conclusion: Since cognitive load rhythmic games have a positive effect on the theory of mind in children with developmental coordination disorder, it is recommended that these exercises be included in the daily activities of these children.

Introduction

One of the disorders observed among primary school-aged children is developmental coordination disorder (DCD) or dyspraxia, which affects motor skills in otherwise normal and healthy children. This disorder is a type of growth retardation in children, and it does not appear to have a specific medical, environmental, and intelligence cause [1]. Some researchers have suggested abnormal brain development as a cause of developmental coordination disorder [2]. Some problems such as growth retardation, balance disorder, perceptual disorder, physical awkwardness, and poor motor coordination, and to some extent, psycho-neurological disorders have been reported for this disorder [1]. The prevalence of this disorder is reported to be 5%-6% in children aged 5-11 years. According to previous studies the number of boys with this disorder is more than that of girls and the ratio of boys to girls is from 2/ 1 to 7/ 1 [3].

Recent studies have shown that children with DCD are significantly weaker in cognitive functions than healthy ones. These children participate less frequently in team and physical activities than their healthy peers, which in turn leads to their social withdrawal [4, 5].

According to a study by Katrina (2012), there is a significant relationship between cognitive and motor

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processes. These processes are a set of activities that engage the mind and deal with cognitive factors such as intelligence, processing speed, and memory. Moreover, parents of DCD children have stated that their children are often lonely and introverted and lack the necessary social skills [6].

Theory of mind (TOM) is a subset of social skills. It lies at the heart of social relationships and broadly refers to the ability to understand others' emotions, motivations, thoughts, and subsequently behaviors. Besides, some cognitive abilities such as intelligence, processing capacity, and memory affect the theory of mind [7].

Individuals can be placed on a continuum in terms of their abilities of the theory of mind. At one end are people with advanced abilities, and at the other, those with impaired ones. Several factors can affect the theory of mind. Damaging conditions often lead to this advanced metacognitive ability deficiency, other cognitive abilities being normal [8].

Furthermore, children with DCD have impaired active memory, as one of the factors affecting the theory of mind. They have also shown deficiency in everyday memory, especially verbal and visual [9]. Abnormal sensory processing in DCD children affects participation in purposeful activities such as playing with other children or participating in social activities. However, these activities are often the most common programs used to treat these children [6].

Researchers indicate that there is a strong relationship between playing activity and cognitive development. The simultaneous use of music and rhythm (in the form of rhythmic games) leads to increased nerve branches [10].

In rhythmic movement games, the child is obliged to observe the predetermined patterns of the game, and if these are repeated and practiced, room is provided for the improvement of memory scales, especially active memory. Research shows the effectiveness of physical activity and rhythmic exercise on memory and learning [11, 12].

In a study conducted by Chapman et al. (2013), it was found that cognitive training increased neural activity and communication during the brain resting state. Physical activities with a cognitive load promote cognitive ability (beyond exercising alone) [13, 14]. Cognitive load in physical activity refers to the load of working memory during training [15]. Cognitive load theory is based on some basic assumptions about human cognitive structure, long-term memory, and working memory [16]. A review of the research literature highlights that despite a great deal of studies on the role of various physical activities in terms of intensity and duration on cognitive functions, very little attention has been paid to the effect of exercises in terms of cognitive load. Research on the theory of mind in children has become widespread over the past two decades, but it has mostly examined this theory in children with autism and mental retardation, and the effect of this cognitive ability on other disorders have been less investigated. Therefore, research on children with DCD seems necessary. The present study aimed to investigate the effect of rhythmic games with cognitive load on the theory of mind in children with developmental coordination disorder, and the researchers seek to answer the following question: Does rhythmic games with cognitive load have any effect on improving the theory of mind in children with DCD?

Methods

This is a quasi-experimental study with a control group pretest-posttest design. The participants in this study were 25 male and female students aged 8-10, from the primary schools of Jarqavieh Olya Rural District of Isfahan County, who were selected through convenience sampling, based on the inclusion criteria. To conduct the research, an introductory meeting was held with parents in coordination with school principals. In this meeting, all the practical and ethical considerations of the research were explained to the parents in detail. Parents who wished their children to participate in the research signed an informed consent form. The Developmental Coordination Disorder Questionnaire (DCD- Q07) was then completed by the parents according to their child's characteristics. Children with a score below 47 and no history of heart disease or musculoskeletal injuries were selected as DCD participants and underwent Raven's Coloured Progressive Matrices Test in the same conditions. Students with normal intelligence (90-110) entered the study. Participants in the experimental (n=13) and control (n=12) groups were age-, gender-, and DCD degree-matched. Both experimental and control group played rhythmic games. The experimental group participants were subject to cognitive load and those in the control group were not. Before and after the interventions, the Motor Development Evaluation Test (MABC) and the Stirmann Mind Theory Test were taken as pre-tests.

Training protocol: The training protocol in the present study was performed for eight weeks and two sessions of 45 minutes per week. Rhythmic games were played using balls, hula hoop rings, conical obstacles, and coloured ribbons. Each training session was divided into three stages; a) Warming up for 5 minutes b) The basic training: playing rhythmic games with music for both groups and performing exercises in the form of a game with cognitive load for the experimental group and without cognitive load for the control group for 35 minutes, and c) Recovery workouts for 5 minutes.

Rhythmic games with cognitive load consisted of imagining a six-cell grid in space, or underfoot, and performing movements on them. The grid on the ground was numbered from one to six. In the first stages of the game, the child stood outside the grid and, when the instructor called out a number, jumped inside the relevant cell, hopped, sat, or touched the cell with a hand. In the advanced stages of the game, the numbers were changed to the names of the students or the names of the flowers. In the next stages, numbers, the names of the flowers and students were removed from the cells and the student needed to remember the cells they were written in and continue to play the game. In the last sessions of the training protocol, the student was asked to play the game by imagining the grid on the ground or in the air in front of them, and pointing what was called out by the instructor.

The research tools included the following:

- The Developmental Coordination Disorder Questionnaire (Wilson et al., 2009) is a measure that helps parents to identify developmental coordination disorders in children. In the questionnaire, parents are asked to compare their child's motor performance with their peers using the five-point Likert scale. According to the evaluation table for children aged 8-10, a total score of 15-46 is defined as having or being prone to DCD and 47-75 as lacking DCD. The reliability coefficients of this inventory have been reported to be 0.83, 0.93, and 0.85 in Iran by internal consistency, retest, and Cronbach's alpha methods, respectively [17].

- Raven's Coloured Progressive Matrices Test is one of the non-verbal intelligence assessment instruments used to measure fluid intelligence. The shortened version of this test consists of 36 questions, which are designed in colour, to be used for children aged 5-11 years. The correlation coefficient of this test is 0.40-0.75, using Stanford Binet and Wechsler tests, and its validity has been reported to be 0.70- 0.90 in older ages and somewhat less in lower ages. This tool is used in Iran to measure the intelligence of the child to enter the interventions [18].

- Motor Development Assessment (MABC) test includes manual skills, static and dynamic balance, and ball skills. This is a norm-referenced test and is used for children aged 4-11. This test has eight items. Children can get a score from zero to 5 on each item. So the total score varies from zero to 40. A score above 15 is identified as having developmental coordination disorders. The reliability and validity of the tool, which were tested, in Isfahan, in 2013, lie within an acceptable range. The reliability between assessors is 0.98, using the mean intraclass correlation coefficient. The average intraclass correlation coefficient for test-retest is 0.77 [19].

- The 38-question Test for the theory of mind was developed by Stirnman (1999) to assess the levels of theory of mind in children. This test is designed to assess the theory of mind in 5-12 aged normal children as well as in children with pervasive developmental disorders and provides information about the child's range of social perception, sensitivity and insight, and the degree to which he is able to understand other's thoughts and feelings. This test includes three subscales: emotion recognition, false belief understanding and second-order false belief understanding. The total score of the theory of mind is obtained by summing the scores from the above three subscales. The higher the score, the higher the level of the theory of mind the child has reached. The scoring method is that the subject's correct answers are given a score of one, and incorrect answers are given a score of zero. Subjects can get a score from 0 to 20 on the first sub-test, a score from 0 to 13 on the second, a score from 0 to 5 on the third, and thus from 0 to 38 on the entire test. The correlation coefficients between the scores of the subtests and the total test were significant and ranged from 0.82 to 0.96. All correlations were significant at the 0.01 level. The internal consistency obtained was 0.86, 0.72, 0.80, and 0.81 for the total test and each subtest, respectively, by using Cronbach's alpha. Also, the validity coefficient of the scoring was 0.98 [20].

Data analysis was conducted, based on the assumptions of the statistical tests, using univariate and multivariate analysis of covariance. Statistical analysis was done by SPSS statistical software version 23 at $\alpha \leq 0.05$.

Results

Tables 1 and 2 describe the motor skill development and the theory of mind and its subscales in the experimental and control groups.

Based on the values shown in Table 1, regarding the average index, as the most important index concerning the research objectives, a difference is seen between experimental and control groups in terms of the mean scores of the motor development variable and its subscales, the scores being higher in the experimental group than in the control group.

As seen from Table 2, there is a difference between the two groups in terms of the mean scores of the theory of mind and its subscales in pre-and post-test phases, the scores being higher in the experimental group than in the control group for both tests.

Table 1: Description of Motor Development Variable and its Subscales in the Experimental and Control Groups

Variable	Experimental		Control	
	Mean	SD	Mean	SD
Movement Skills	24.54	1.76	23.8	4.48
Manual Dexterity	8.08	1.25	8.92	1.93
Ball Skills	6.38	1.19	5.92	2.54
Static and Dynamic Balance	10.08	0.95	8.25	2.56

Table 2: Description of the Theory of Mind Variable and its Subscales in the Experimental and Control Groups

Variable	Phase	Experimental		Control	
		Mean	SD	Mean	SD
Theory of Mind	Pre-test	28.08	1.38	27.54	2.66
	Post-test	32.61	0.51	31.72	1.10
Emotion recognition	Pre-test	15	1.68	14.63	1.91
	Post-test	17.61	0.87	17.45	0.52
False belief understanding	Pre-test	10.69	1.18	10.36	1.50
	Post-test	12.08	0.64	11.36	1.03
Second-false belief understanding	Pre-test	2.31	0.48	2.54	0.68
	Post-test	2.93	0.64	2.89	0.33

Table 3: Analysis of Covariance for Comparing the Mean Theory of Mind Variable between the Experimental and Control groups

Dependent Variable	Group	Marginal Sean	SD	Sum of Square	DF	Mean Square	F Statistic	Sig	Eta-Squared
Theory of Mind	Experimental	32.46	0.27	6.98	1	6.98	7.92	0.011	0.29
	Control	31.33	0.28						

The estimated assumptions of ANCOVA have been met. The values of Wilks' lambda and the significance level of the test for the difference between the experimental and control groups in terms of the mean scores of the theory of mind and its subscales indicate a significant difference between the two groups (P=23% and Eta-squared=49%). However, the analysis of covariance was performed for a more detailed investigation of the difference between the means of the two groups (Table 3).

The estimated values in Table 3 indicate that there is a significant difference between the experimental and control groups in terms of the mean theory of mind in the post-test (Sig≥0.05). In other words, the mean theory of mind variable was significantly higher in the experimental group than in the control group.

Discussion

The purpose of the present study was to investigate the effect of increasing cognitive load of rhythmic games on the theory of mind in children with developmental coordination disorders. The research results showed that rhythmic games with cognitive load improved the theory of mind in these children. The results of our study were in line with findings from some prior studies. Navidinejad et al. (2016) examined the effect of rhythmic-music movements on the performance and the theory of mind in autistic children. Their findings showed that rhythmic-music programs lead to improved performance and theory of mind in these children [21]. Farsi et al. (2015) studied the effect of cognitive training on attention and accuracy of motor responses and concluded that these activities are essential to improving attentional control [22]. Studies by Eichenberger et al. (2015) and Moreau et al. (2015) suggested that the interactions of physical activity and cognitive challenges lead to more improved cognition. These researchers concluded that regular physical activity significantly improves memory function and enhances learning by compatibilities adjustment of the central nervous system, especially the hippocampus [23, 24]. In this regard, Karmili et al. (2008) stated in a study that rhythmic movements could affect cognitive processes, attention, perception, concentration, neuromuscular coordination, and the development of personal relationships and social skills [25]. However, our results are not consistent with the findings of some other researchers. In a study, Eskandarnejad et al. (2016) showed that aerobic exercises with and without cognitive load had no impact on the effectiveness of this type of exercise on the attention alert network [26]. The results of studies by Chang et al. (2015) and Bailey et al. (2014) revealed that there was no difference between the effectivity of various sports activities in terms of complexity and coordination of movements on cognitive functioning in young adults, especially attention [27, 28]. To explain these findings, Chivia Kofsky and Wolf (2008) stated that learning progression diminishes if the cognitive requirements of the training conditions outgrow the learner's ability to process information [29].

To explain the results of the present study, it can be said that based on the theory-theory approach (a theoretical approach of the theory of mind), the development of the theory of mind ability in children requires the improvement of their understanding of mental states and human psychology. According to this approach, team games and physical activities play an essential role in increasing communication with peers, recognizing their and others' emotions, understanding the concepts of camaraderie and friendship, and ultimately improving the theory of mind in children [30].

From the information processing viewpoint, central memory plays an important role in cognitive development. Enhanced memory is associated with cognitive load. There is an assumption that memory storage capacity, and consequently, learning gains is related to the type and the cognitive load levels of the exercise [6]. Therefore, since children with DCD have poor accuracy and attention [1], playing games increases the learning speed in these individuals because games are a combination of cognitive training and motor exercise. Rhythmic games and participatory exercises have a significant effect on memory recall. The effect of facilitation observed on memory performance following team games is because these activities are open skill exercises (performing in changing and unpredictable environments) characterized by rapid changes in conditions and memory, high interpersonal variability, and instant decision making [31].

Since memory is one of the factors affecting the theory of mind, participating in team games with cognitive load improves various aspects of the children's memory [31]. Being engaged in rhythmic motor games leads to improved cognitive concepts in children. Repetition of a regular pattern during a rhythmic movement enables children to predict what will happen next; in other words, to anticipate the next components of the movement by using their memory. Maintaining rhythm in rhythmic motor games improves memory and reduces its performance scale problems [4]. Therefore, games with cognitive load are likely to affect memory as a factor affecting the theory of mind.

To explain the effectiveness of cognitive training from a neurophysiology point of view, we can argue that regular physical activity improves neurotrophy and thus cognitive functions such as processing speed, control and programming strategies, and practical memory through control, maintenance, growth, and differentiation of neurons, synapse formation, and angiogenesis. Moreover, due to their progressive cognitive load, these exercises increase the processing capacity of neural messages and raise the secretion of dopamine and acetylcholine by regulating neurotransmitter levels, which help in maintaining nervous system functions and improving cognitive functions [32].

Although the results of the present study could be explained from several viewpoints, further research is needed to confirm these findings and to support the effectivity of the designed exercises. Since there are consistent findings on the different prevalence of DCD among girls and boys [3], it is suggested that subsequent researchers examine the role of gender in the effect of rhythmic games on the theory of mind in these children. Also, it has been revealed that social and economic status affect the scores obtained from the DCD-Q07 questionnaire [17]; therefore, it is suggested that subsequent studies should address this issue.

Conclusion

The results of our study showed that game-based interventions, especially rhythmic games, affect cognitive, emotional, and social functions directly or through other mechanisms or processes and pave the way for communication enrichment as well as training and improving social cognition structures such as the theory of mind. These exercises can be used as a treatment method or supplementary treatment in individuals with developmental coordination disorders. Authorities in charge of Physical Education in the Ministry of Education and rehabilitation centers, also, parents of these children, are recommended to include rhythmic games in designing sports movements and recreational activities for children.

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