Article

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Dancing Effects on Preschoolers' Sensorimotor Synchronization, Balance, and Movement Reaction Time

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Abstract

In the present study, we compared an experimental group of preschool children ($n = 22$; mean age = 5 years, 8 months) who followed an 8-week dance program with a control group ($n = 20$; mean age = 5 years, 5 months) on pre–post measures of sensorimotor synchronization (K-Rhythm Test), balancing on one leg and movement reaction time. Compared with the control participants, the dance group demonstrated significantly better pretest to posttest improvements on sensorimotor synchronization and balance (but not movement reaction time). Considering the importance of sensorimotor synchronization and balance for subsequent child development and performance of daily and sport activities, these results suggest that dancing should be included in early childhood curricula.

Keywords

dance, rhythmic synchronization, children, early childhood education, preschool

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Introduction

"When I dance I am feeling free and truly alive," responded 11-year-old Billy to his father's question of why he loves to dance in the movie *Billy Elliot*. The freedom people feel when dancing is the sense of finding a space where they can flout day-to-day rules governing the use of their body (Gard, 2008). Perhaps this sense of freedom helps explain the popularity of dancing among young people. Survey research has shown dancing to be the second most popular activity after football among school children (Burkhardt & Brennan, 2012).

In promoting healthy child development, the advantage of dancing, compared with traditional sports, is that it provides an opportunity for young children to be active and to explore body movement capacity without the element of competition (Allender, Cowburn, & Foster, 2006). Based on Laban's work, Stinson (1988) developed a specific dance program for preschool children consisting of four dance elements: body, space, energy, and time. The element *body* refers to what the body does while in movement (e.g., what body shapes are made). The element *space* refers to the space in which a person can move; it encompasses parameters like direction (e.g., forward and backward) and level (high and low). The element *energy* refers to the type of dynamic that is applied to the movement (e.g., strong and light movements). The last element *time* refers to the synchronization of the movement to different music tempi. The foundation of dance education is in learning how the body can move in synchronization with the music's beat (Gilbert, 2015; Koff, 2000; Stinson, 1988).

There have been limited empirical investigations of dance programs for children, and most studies of the effects of dancing on children's development have concentrated on dependent variables that are not directly related to dance. For example, past studies have suggested that dancing may improve children's cardiovascular fitness (Flores, 1995; Robinson et al., 2003) or contribute to healthy weight maintenance (among preschool girls; Gallotta, Baldari, & Guidetti, 2016). Similarly, other studies found that dancing may induce a remission of obesity (Mo-suwan, Pongprapai, Junjana, & Puetpaiboon, 1998), enhance creativity (Garaigordobil & Berrueco, 2011; Jay, 1991), and benefit social competence (Lobo & Winsler, 2006). While these are desirable educational benefits, they might be achieved through other aerobic activities (Alpert, Field, Goldstein, & Perry, 1990; Hannon & Brown, 2008), and they do not inform us as to whether specific motor, sensory, balance, and cognitive skills are improved among preschoolers as a result of their early participation with dance activity.

One principal skill component of dancing is sensorimotor synchronization, defined as the coordination of rhythmic movement with an external rhythm (Repp & Su, 2013). Specialists from dance and music fields might find the term *rhythmic ability* more familiar (Côté-Laurence, 2000; Gilbert, 2015).

Research has previously documented the importance of sensorimotor synchronization for sport performance (MacPherson, Collins, & Obhi, 2009) and even for children's language and literacy development (Thomson & Goswami, 2008). Theoretically, dancing may play a role in developing this synchronization ability among children (Gilbert, 2015), particularly since several studies have reported that professional dancers demonstrate better synchronization than do untrained control groups (Karpati, Giacosa, Foster, Penhune, & Hyde, 2016; Miura, Kudo, & Nakazawa, 2013). To date, the inference that dance may induce these differences among adults with different synchronization skills remains a correlational assumption rather than a causal demonstration. An alternative interpretation of these findings is that dancers' better sensorimotor synchronization may be an inherent biological ability difference between dancers and other persons, leading to dancers' self selection or their selection by experienced dance instructors.

There are, however, a few studies originating from within the music education domain that have investigated the effects of music and movement interventions on preschool children's rhythmic synchronization; and they have reported positive results (High, 1994; Weikart, Schweinhart, & Larner, 1987). Specifically, Zachopoulou, Derri, Chatzopoulos, and Ellinoudis (2003) reported that a music and movement program, based on Orff's approach, improved rhythmic synchronization in preschool children. The improvement of rhythm was attributed to (a) practice with percussion instruments (e.g., tambourines, woodblocks, and triangles) and (b) performing fundamental motor skills in synchronization with music (e.g., walking and hopping; High, 1994).

While music education uses both (a) body movement in synchronization with music and (b) practicing musical instruments in order to develop rhythmic synchronization, dance education involves only body movement in synchronization with rhythm. More specifically, Stinson's (1988) dance program is based on performing fundamental motor skills in synchronization with rhythm. Since a large part of every dance lesson relies on training rhythm and the fundamental motor skills in synchronization with music, the present study focused heavily on synchronization skills as a dependent measure in an evaluation of dance effects among preschool children, consistent with Stinson's (1988) dance conceptualization.

Another key skill for dancing is balance. Most of the movements performed in dancing require well-developed balance, and relevant balance activities are typically included in every dance lesson (e.g., the bird dance involving balancing on one leg; Stinson, 1988). In one study, Zachopoulou, Tsapakidou, and Derri (2004) found that a music and movement program enhanced balance skills in 4- to 6-year-old children. The balance activities of this program were similar to those used in most dance lessons, including moving in space in synchronization with music and stopping in balanced positions with different body shapes when the music stopped. However, since Wang (2004) and Gallotta et al. (2016)

reported no significant effects from dancing on children's balance, a paucity of evidence and varying study results regarding dance effects on children's balance show a need for further investigation.

Besides rhythmic synchronization and balance, executing dance movements also requires a fast response to sound (movement reaction time). Dancers must rapidly change their movement in accordance with hearing certain music accents. An accent is the stress or special emphasis given to certain beats; accent determines the beginning of a measure. Usually the heaviest accent falls on the first beat of the measure, and the regular accentuation of metrically organized music facilitates patterns of dancing steps. In dance lessons, children may become more aware of accent by various games (e.g., moving around the room in synchrony with the beat and changing direction on each accented beat). Kattenstroth, Kalisch, Holt, Tegenthoff, and Dinse (2013) reported that, compared with a matched control group, elderly people (mean age = 68.60; $SD = 1.45$ years) engaged in dancing showed enhanced movement reaction time. Even though movement reaction time is an important factor for dance performance, there are very limited relevant studies in this area; and further research with this variable is also needed.

The present study accepted a premise explaining dance popularity among young children—namely that when children listen to music, they begin to move spontaneously in synchrony with the beat and clearly enjoy this activity (Provasi & Bobin-Bègue, 2003). Yet, as seen by this brief literature review, few prior studies have examined the effects of a dancing skill program on children's development of rhythmic synchronization, balance, and movement reaction time (the ability to quickly respond to music stimuli). Therefore, the present study addressed dancing effects on these variables among preschoolers, with the expectation that children exposed to dance in preschool would demonstrate greater skill improvement in these areas than children who were not exposed.

Method

Participants

Our participant sample consisted of 42 children who attended four classes of an urban preschool (17 boys, 25 girls). We randomly selected two classes of children each for our experimental and control groups. Our experimental group was then composed of 22 children (9 boys, 13 girls) with a mean age 5 years, 8 months ($SD = 8$ months; range = 57–78 months), and our control group consisted of 20 children (8 boys, 12 girls) with a mean age of 5 years, 6 months ($SD = 8$; range = 54–76 months). There was no significant age difference between experimental and control groups ($t = 1.03$, $p = .31$). Apart from the 42 children in the experimental and control groups, 111 other children participated in pilot validity and reliability studies of several of the dependent variable measurements (the K-Rhythm Test and the Movement Reaction Time Test).

Our research was conducted in accordance with the ethical guidelines of the local university, and we obtained informed written consent from the parents or guardians of all child participants with their clear understanding that they could withdraw from the study at any time. No participant withdrew because of injury or any other adverse experience. Our data analysis included only children who were free of acute musculoskeletal injuries, had no previous dance or sport training, and had no diagnosed learning disabilities. The application of these exclusion criteria led to no loss of participants.

Procedure

Our experimental group followed an 8-week dance program which took place twice a week in 45-minute sessions. The program was based on Stinson's (1988) educational principles and included the four essential elements described in the Introduction section of this article:

- *Body* referring to what the body does in movement: (a) which isolated body parts are involved, (b) what action is going on, and (c) what body shapes are made.
- *Space* involving (a) direction (e.g., forward and backward), (b) size (large and small movements), (c) level (high, middle, and low), (d) pathways (e.g., straight, curved, and zigzag), and (e) focus (which way the eyes look—focus may be fixed directly on one spot or may be looking all around).
- *Energy* consisting of (a) tension or relaxation (smooth and sharp movements), (b) weight (strong or light), and (c) flow (free or bound). When someone moves with free flow, it is hard to stop right away (e.g., fast running); *bound flow* refers to releasing energy in a controlled manner so that someone is able to stop the movement promptly.
- *Time* including (a) pulse (underlying beat), (b) tempo (speed of movement), (c) duration (length of time movements last), and (d) phrases (sequences of completed movements).

We introduced these through popular children's songs (Table 1) chosen for their ability to (a) encourage active involvement, (b) relate to children's interests, and (c) present easy-to-learn repetitive phrases and movements (Palmer, 2001). A large part of the program comprised improvisation and reaction movements. For example, children could express their own ideas through movement exploration, and they were asked to react to different accented beats with preassigned movements (e.g., movement direction changes). We also modified traditional games such as "Red light/Green light" and "Chase" to create other dance activities.

The main goal of the introductory lessons was the development of body and space awareness (personal and general space). The children learned (a) to

Table 1. List of the Songs.

Songs
One Little Finger
Head Shoulder Knees and Toes
If you 're happy
Hokey Pokey
Clap your hands
The Twist
Let's Star Jump!
Everybody Dance

identify their body parts and (b) to move (e.g., walk or jump) on different pathways (e.g., curved and straight). Furthermore, they were encouraged to explore their own personal rhythm and to execute movements in synchronization to this rhythm (e.g., clapping or walking in their own preferred rhythm). In the next phase, children learned (a) to express the different intensities of sounds with movements in different levels and (b) to respond to the accented beat by changing their movement directions or shapes. The next step included synchronization of movements to externally imposed rhythm. The teacher presented different tempi and simple rhythmic patterns with a tambourine, and the children were encouraged to express them with fundamental motor skills, for example, walking in synchronization to quarter (about 120 beats/min). Throughout the intervention, they were encouraged to improvise and to produce their own rhythmic phrases with combinations of fundamental motor skills, and in this way, the complexity of the activities was gradually increased.

Each lesson consisted of three phases—a warm up (aerobic activity games), a period of exploring the elements of movement (e.g., body awareness), and a cooling down phase (good-bye dance). During the same period of time and for the same amount of time in which the experimental group was engaged in these various dance activities, the control group participated in unstructured free-play activities involving fundamental movement skills (Tuesday 10:00–10:45 dance group, 11:00–11:45 control group and Thursday 10:00–10:45 control group, 11:00–11:45 dance group). A physical educator with experience in dance instruction with young children taught and supervised free play in the treatment and control groups, respectively. All sessions were conducted in the multipurpose hall of the preschool center (size $12\,\text{m} \times 14\,\text{m}$).

Measures

Before and after the 8-week dance intervention or unstructured free play experience, we administered three tests to all children so as to measure their rhythm, balance, and movement reaction time skills.

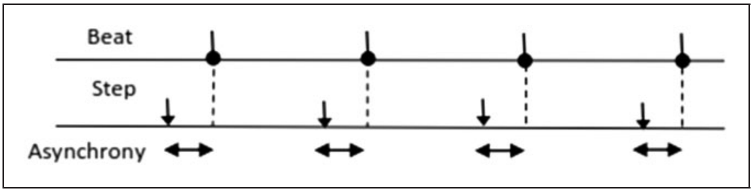

Figure 1. Asynchrony represents the temporal absolute difference between beat and the corresponding foot contact.

Rhythm test. We measured rhythmic synchronization with the K-Rhythm Test. This test utilized a software program and two force plates (20 × 30 cm), connected to a computer (KINVENT, www.k-invent.com). The participant was asked to walk in place on the two force plates in synchrony with a steady beat produced from the software system (metronome). The software captures both the time of the metronome onset (beat) and the participant's corresponding foot contact on the force plate (sampling frequency 100 Hz) and then measures rhythmic accuracy (or asynchrony) as the temporal absolute difference between the beat and the corresponding participant's foot contact (see Figure 1). We used the mean of the absolute differences for statistical analysis.

We acquainted participants with the apparatus prior to this measurement. In accordance with the "High/Scope Beat Competence Analysis Test," children were asked to step in time on the steady beat of 120 beats/minute (Weikart et al., 1987). The children executed 16 steps in synchrony to the beat of the metronome. The test was conducted in a quiet room, and the intensity of the acoustic stimulus was set individually at a level declared comfortable by the children.

The K-Rhythm Test has face validity, as it measures the absolute temporal difference between the beat and the corresponding foot contact (Figure 2), the definition of asynchrony (Elliott, Welchman, & Wing, 2009). Similar methodology has been used by many other studies where participants tapped, either on a footpad (Rosenblum & Regev, 2013) or on the mouse button of a computer in synchronization with the beat of the metronome (Bailey & Penhune, 2010). In addition, we validated the test's capacity to distinguish age-groups in a pilot study with 80 children (5–8-years-olds, Table 2). The analysis of variance (ANOVA) results showed that older children had better rhythmic synchronization than younger ones ($F = 8.84$, $p < .001$, $\eta^2 = .25$). More specifically, post hoc Bonferroni tests revealed that 7- and 8-year-old children were significantly better on this measure of rhythmic synchronization, compared with 5-year-olds, and the 8-year age-group was also significantly better, compared with 6-year-olds (Table 2). Comparable results were reported by Kuhlman and Schweinhart (1999), who used a similar computer-based measurement, the Interactive Metronome. The reliability of this test was determined by one week test–retest administrations within our pilot study with 16 preschool children for which the

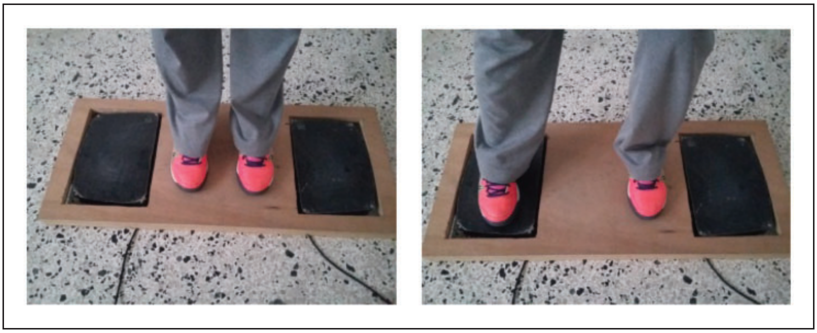

Figure 2. Movement reaction time measurement. The person is a model who did not participate in the study.

Table 2. Rhythmic Synchronization by Age-Group (ms).

Age	*N*	*M*	*SD*
5	20	173.41	31.19
6	20	154.82	37.44
7	20	139.56*	35.93
8	20	117.00*,†	38.68

N = number of participants.
*Significant difference between the age 7 and 8 years groups compared with the age 5 years group ($p < .05$).
†Significant difference between the age 8 years group and the age 6 years group ($p < .05$).

intraclass reliability coefficient (ICC) was satisfactory (ICC = .70). As noted earlier, participants in the validity and reliability pilot studies were not included in the main study.

Static balance. We used the test of balancing on one foot for assessing static balance (Bös, Bappert, Tittlbach, & Woll, 2004). For this task, participants balanced on a bar three centimeters (cm) wide and five centimeters (cm) high. They were asked to stand on their dominant leg for 60 seconds with their eyes open, keeping their leg in the air like a stork. During the test, each ground contact with the free leg was recorded as a penalty point, and the test was discontinued after 30 points were acquired. Points were summed, and we used the total points attained by each participant for data analysis. In this way, the fewer the number of ground contacts participants made with the free foot, the better their balance. This test has shown good test–retest reliability ($r \geq .70$) and validity for measuring balance (Bös et al., 2004).

Movement reaction time. We measured movement reaction time with an apparatus developed by KINVENT (www.k-invent.com) and a task that entailed movement of the dominant foot in response to an auditory stimulus. Upon listening to the auditory stimulus (after a forewarning of 2–3 seconds, randomized across trials), participants performed a fast movement (side step) of the dominant foot to a nearby force plate (20 cm distance; see Figure 2). Movement reaction time was defined as the time between onset of the stimulus and the participant's foot contact with the force plate. Participants completed one practice attempt and three trials on the day of testing with 30-second rest periods (Cronbach's Alpha ICC for the three trials $a = 0.73$). The mean of the three trials was used for data analysis. The reliability of this test was determined by test–retest in a pilot study with 15 preschool children who were not involved in this study, with the reliability testing group retested 1 week after the initial test. We found a satisfactory intraclass reliability coefficient (ICC = .72).

Statistical Analyses

To test for differences between the experimental and control groups, we analyzed data for all three dependent measures of rhythm synchronization, balance, and movement reaction time using one-way ANOVA for repeated measures. We conducted any necessary post hoc analyses with Bonferroni pairwise comparisons. All statistical analyses were conducted using SPSS (version 20), and we set the level of statistical significance at $p < .05$.

Results

Descriptive statistics for the participants' performance on all three dependent variables at both pre- and postintervention are presented in Table 3.

For the rhythm synchronization variable, the repeated measures ANOVA showed a significant interaction effect between group (dance program vs. control) and time of measurement (pre- vs. postintervention), $F(1, 40) = 4.927$, $p = .032$, partial eta-squared $\eta_p^2 = .110$. At preintervention, there were no significant differences between the two groups (treatment, control, $t = .123$, $p = .903$), but, at postintervention, the dance group performed significantly better in rhythm synchronization, compared with the control group ($t = 2.177$, $p = .035$, 95% CI [.029, .001], Cohen's $d = .694$).

On the balance measure, the repeated measures ANOVA again showed a significant interaction effect between group (dance program vs. control) and time of measurement (pre- vs. postintervention), $F(1, 40) = 4.575$, $p = .039$, partial eta-squared $\eta_p^2 = .103$. At the preintervention testing, there were no significant group differences (dance group vs. control group), $t = .559$, $p = .579$. At the postintervention testing, the group exposed to the dance program showed

Table 3. Rhythm (ms), Balance (Contacts), and Movement Time (ms) Performance of Treatment and Control Group in Pre- and Postmeasurement.

	Treatment				Control			
	Pre		Post		Pre		Post	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Rhythm (ms)	140.59	40.14	108.65*	41.98	142.05	36.29	138.92	48.14
Balance (contacts)	16.47	5.28	11.29*	6.11	17.47	6.27	16.02	6.05
Movement time (ms)	1078.18	238.51	969.76	222.09	1046.5	261.98	991	269.77

*Significant difference between treatment and control group.

significantly better balance, compared with the control group, $t = 2.516$, $p = .016$, 95% CI [8.528, .930], Cohen's $d = .796$.

With respect to movement reaction time, the repeated measures ANOVA indicated no significant interaction effect between group (dance program vs. control) and time of measurement (pre- vs. postintervention), $F(1, 40) = .418$, $p = .522$, partial eta-squared $\eta_p^2 = .010$). There were no significant differences between the two groups, either at preintervention or postintervention testing, $t = .410$, $p = .684$, and $t = .282$, $p = .779$, respectively.

Discussion

As rhythmic synchronization, balance, and movement reaction time have all been found to be crucial factors for the successful execution of dance and other daily and sport activities (MacPherson et al., 2009; Myer et al., 2011), we investigated the effects of a dance program for preschool children on all three of these variables. We based the dance education program on Stinson's (1988) theory of what might enhance these skills. Children receiving this 8-week dance intervention, compared with a control group engaged in free play that encouraged use of fundamental motor skills, made greater gains from pretest to posttest with respect to both rhythm synchronization and balance, but they were no more improved than the control group with respect to movement reaction time.

Our finding of greater improved rhythm synchronization skills for preschoolers involved in dance instruction than for those in the control group is consistent with past music education research (High, 1994; Weikart et al., 1987; Zachopoulou et al., 2003) in which there were usually motor skill performances during training (e.g., walking and hopping in synchrony with music) that resembled dance lessons (High, 1994). However, these studies mainly sought to teach music skills and principally focused on practice with rhythm music instruments (e.g., tambourines, woodblocks, and triangles). Therefore, these studies are not directly comparable to ours. Our study was the first to focus specifically on the effects of organized dance activities on rhythmic synchronization in young children. While some prior research has shown better rhythm synchronization among dancers than controls within adult populations (Karpati et al., 2016; Miura et al., 2013), those studies provided no causal link between dance training and this higher level of rhythmic synchronization. As participants in our study were untrained preschool children exposed or not exposed to dance activity, our research design permits a causal inference between dance training and better rhythm synchronization in preschoolers, implying benefits to dance for subsequent child development and daily living and sports skills. Of course, our findings should be replicated with a larger number of participants of greater diversity.

A possible explanation for the positive effects of Stinson's (1988) program on children's rhythm may be this program's unique content. Specifically, the program encourages children to express their emotions in synchronization to music with basic motor skills and not with specific dance steps (e.g., ballet steps). Therefore, children had the opportunity to experience the pleasant feelings associated with dancing without fear of doing something incorrectly, and they were not limited in their motor explorations. Each child's contribution was valued, and movement diversity was appreciated. Perhaps these pleasant experiences kept children's' interest high during dancing activities, leading to their improved rhythmic ability. Furthermore, children were encouraged to explore the elements of space (e.g., directions, levels, and pathways) by moving in synchronization to specific tempi. Indeed, past studies have reported that movement experiences requiring spatiotemporal acuity may enhance rhythmic synchronization (Miura, Fujii, Yamamoto, & Kudo, 2015). Although the exact mechanism leading to an improvement of rhythmic ability remains unknown (Miura et al., 2015), it seems that Stinson's (1988) dance program made a positive contribution to the development of children's rhythm, and future studies should explore the exact mechanism underlying that benefit.

According to Drewing, Aschersleben, and Li (2006), rhythmic synchronization continues to improve substantially during childhood and late teen years and then remains stable until old age. Since we showed that exposure to an 8-week dance program significantly enhanced rhythmic synchronization in a group of preschool children, relative to others in a control group, future work should examine whether dance programs of this kind might enhance the trajectory rate and magnitude of normal motoric development.

Turning to balance, balance ability also influences the development of basic motor skills, and dance opportunities should be an attractive means of helping young children improve it (Butterfield & Loovis, 1994). Almost all dancing movements require a well-developed balance ability, and our findings of improved balance among participants exposed to dance, relative to those who were not so exposed, corroborates findings of those earlier studies showing beneficial effects of dancing on balance (Boswell, 1993; Zachopoulou et al., 2004) and contradicts Wang (2004) who reported no significant effects of dancing on children's balance. A possible explanation for these varied results may be different lengths of the dancing intervention across studies. In Wang (2004), the dance intervention lasted six weeks, and sessions were limited to 30 minutes twice a week, whereas our study employed an 8-week intervention with two 45-minute sessions per week. Future research should continue to address this controversy.

Quick reactive movement ability is directly linked to dancing activity, and we also expected skill improvement in this area from early exposure to a dance program. However, unlike other research on this measure (Kattenstroth et al., 2013), we found no significant difference between our dance-exposed and control group participants in reactive movement reaction time. Our different results could be due to our having worked with young children, while Kattenstroth et al. (2013) studied elderly people. Rapid movement skills are known to improve and become more variable with age (Der & Deary, 2006), and a person's physical activity appears to play an important role in the development of movement reaction time performance (Spirduso, 1980). There is a clear need for more research with different age-groups to better understand this variable.

An important limitation of our study was our relatively small participant sample size. This weakness limits generalizability of our findings to other populations and raises the possibility that our failure to find group differences on the movement reaction time variable may have been due to insufficient statistical power for detecting those differences. It will be important to cross-validate our findings in research using a larger participant sample size.

Dance or movement therapists have emphasized the particular benefits dancing has on children with autism spectrum disorder (ASD; Scharoun, Reinders, Bryden, & Fletcher, 2014). In fact, several prior studies revealed that dance therapy increases synchronous movement and improves the social skills of children with ASD (Hartshorn et al., 2001; Scharoun et al., 2014). Since Stinson's (1988) dance program consists of fundamental motor skills, and all children can participate regardless of their physical abilities, this intervention may have particular relevance for children with ASD, and this should be studied further in the future. Meanwhile, there are clear implications from these findings for potential benefits to normally developing children from early dance activities, and there is a basis in these results for incorporating dance in early childhood education.

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