Dyadic Drum Playing and Social Skills: Implications for Rhythm-Mediated Intervention for Children with Autism Spectrum Disorder

Ga Eul Yoo
Department of Music Therapy, Graduate School, Ewha Womans University, Seoul, Korea

Soo Ji Kim
Music Therapy Education, Graduate School of Education, Ewha Womans University, Seoul, Korea

Current perspectives on social skills development of individuals with autism spectrum disorder (ASD) emphasize the interplay between motor and social skills. Given the evidence supporting this relationship, studies are needed to explore the potential benefit of rhythmic behaviors to improve social skills in children with ASD. The purpose of this two-part study was to confirm the relationship between dyadic drum playing and social skills and to further develop a rhythm-mediated music therapy intervention for improving the social skills of children with ASD. In Study 1, we conducted a factor analysis to examine whether dyadic drum playing was related to social skills in 42 children with typical development and 10 children with high-functioning ASD. In Study 2, we conducted a preliminary pilot of a rhythm-mediated music therapy intervention with eight children with ASD and measured changes in social skills (e.g., imitation and engagement in joint action with others) and dyadic drum playing behaviors. Study 1 findings included identification of four factors related to dyadic drum playing. The presence of rhythmic cueing and tempo adjustment correlated with social skills, providing a strong rationale for the use of dyadic drum playing to address social skills. In Study 2, participants showed decreased asynchrony when tapping with a partner at adjusted tempi after the rhythm-mediated intervention. Furthermore, participants showed greater...
engagement in joint action following the intervention. This study supports potential benefit of the rhythm-mediated intervention using dyadic drum playing and provides preliminary evidence strengthening its use in the social domain for individuals with ASD.

**Keywords:** autism spectrum disorder; social skills; dyadic drumming; rhythm mediation; intervention

Children with autism spectrum disorder (ASD) show atypical development or persistent deficits in social skills, which is a primary diagnostic feature of the disorder (American Psychiatric Association [APA], 2013). A newer approach to understanding the mechanisms behind social skills development emphasizes the interplay between cognitive and motor abilities in learning a social behavior. This approach moves beyond cognition-focused perspectives and embraces motor dimensions of social skills through shared or exchanged actions (Amos, 2013; Fitzpatrick, Diorio, Richardson, & Schmidt, 2013). As such, emerging studies indicate that motor development is related to social skills development in children with ASD (Knoblich & Sebanz, 2008; Koehne, Hatri, Cacioppo, & Dziobek, 2016).

Motor dysfunction of children with ASD, including poor coordination of the upper or lower extremities and impaired performance of movement sequences (Bhat, Landa, & Galloway, 2011), limits these children’s ability to engage in social experiences (e.g., play activities) with peers (MacDonald, Lord, & Ulrich, 2013). Disruption in the neural pathways for processing kinesthetic sensory feedback impedes development of voluntary control over motor movement, which may lead to limited adaptation to a social context in time (Torres et al., 2013). For example, individuals with ASD may show limited understanding of the bodily responses of others who intend to interact with them and may exhibit restricted or random movements in response to the movements of others. Furthermore, difficulties in transferring perceived motor information into one’s own movements have been found to limit the ability of children with ASD to imitate observed behaviors (Casartelli, Molteni, & Ronconi, 2016; Vanvuchelen, Roeyers, & de Weerdt, 2007) and interfere with maintaining synchronous movements with others (Marsh et al., 2013; Pierno, Mari, Glover, Georgiou, & Castiello, 2006).
As such, volitional engagement in controlled motor movement is associated with social and communicative development (Knoblich & Sebanz, 2008; Koehne et al., 2016), and engagement in synchronous movements was predictive of empathic abilities (Behrends, Müller, & Dziobek, 2012). Increased activity was found in the neural network for cooperation and emotional processing while adjusting to a partner’s movement during the synchronization task (Fairhurst, Janata, & Keller, 2013). In addition, synchronized movements were significantly correlated with perceived feelings of connectedness among involved partners (Lakens, 2010; Valdesolo, Ouyang, & DeSteno, 2010).

Such increasing evidence for the relationship between motor and social skills (Bhat et al., 2011; Leonard & Hill, 2014) has resulted in the need for change in interventions that address social skills development of children with ASD. Thus far, a broad range of training strategies have been developed to address social cognitive skills and motor functioning independently (Rao, Beidel, & Murray, 2008; Reichow & Volkmar, 2010; White, Keonig, & Schaill, 2007). Contrary to repeated documentation about motor dimensions of social skills development, approaches that address motor functioning within a social domain, referred to as social motor skills, are rarely discussed in the clinical literature (Casartelli et al., 2016). Accordingly, there are calls for interventions that target motor aspects when addressing atypical social skills development with children with ASD, and that such interventions be based on theoretical and empirical evidence (Pierno et al., 2006).

Meanwhile, as with the APA reclassifying ASD as a neurodevelopmental disorder (APA, 2013), its symptoms need to be explained primarily in terms of disorder-specific dysfunctions in neural networks. This supports the possibility of using established findings of how musical elements can meet the specific needs of individuals with neurological disorders to also guide the use of music to support the needs of those with ASD. Given that perceptual and motor processing needs are important to improve the development of the social skills in this population, rhythm, as predictable temporal information, can be an effective agent, as it intervenes in both processes (Thaut, McIntosh, & Hoemberg, 2014).

In the music therapy literature, the use of rhythmic cueing, defined as the provision of regularly paced external stimulation,
was found to improve sensorimotor processing and motor control in individuals with neurological impairment (Wittwer, Webster, & Hill, 2013). As such, the effects of rhythmic cueing on populations with other neurologic conditions may have implications for improving social motor skills in children with ASD as well. Furthermore, research has shown that individuals with ASD possess intact internal timing (Falter, Noreika, Wearden, & Bailey, 2012), which makes the potential effects of rhythmic cueing even more promising. It follows that incorporating aspects of rhythmic cueing into interventions for individuals with ASD holds great promise, essentially given the increasing emphasis on sensorimotor functioning when intervening with this population (Hardy & LaGasse, 2013).

With regard to the social skills of individuals with ASD, several music interventions have been found to generate favorable outcomes in social attention, social engagement, initiation of social interaction and/or communicative behaviors, self-control, and emotional reciprocity (Accirdino, Comer, & Heller, 2007; Geretsegger, Elefant, Mössler, & Gold, 2014; Yoo, 2016). For example, early music therapy intervention literature focused on addressing stereotypical behaviors such as aberrant vocalizations in children with ASD (Brownell, 2002; Pasiali, 2004). More recently, musically structured information has been used to facilitate the accurate processing of such social information by providing a context for a shared relationship (Kalas, 2012). In addition, musical cues for directing attention have effectively elicited orientation to a partner (Yoo, 2014). Based on the individual issues addressed, these approaches support a social cognitive perspective that emphasizes how children learn to perceive others in social contexts and to understand what is expected of them and what are the consequences of their behavior.

Given increased research highlighting motor dimensions of social skills development, there is a need to develop interventions that place greater emphasis on the execution and control of movements at the sensorimotor level as a means to improve social function among children with ASD. A recent study (LaGasse, 2014) involved the use of rhythmically structured music for gross motor movement, as well as imitative or cooperative movement as part of a group music therapy intervention to improve the social skills of children with ASD. Along with the affirmation that the uses of
rhythmic structure are linked to functioning as proprioceptive input and anticipatory cues for upcoming sensation or expected movements, the positive changes in social cognitive behaviors (e.g., joint attention) in the study could reinforce rhythm-based approaches to social skills in this population.

Building on our review of the extant literature, we hypothesized that a rhythm-mediated intervention would be effective for enhancing the social skills of children with ASD. More specifically, we used rhythmic cueing (i.e., regularly paced beat) when eliciting engagement in synchronization by presenting predictable timing information that could facilitate a child’s planning and execution of specified movements. We expected that such an approach would influence how children with ASD controlled their behaviors to match direct auditory cues or perceived timing of another’s movements.

In addition, we used dyadic drum playing as a target behavior to facilitate synchronous movements (i.e., movements that are maintained for a certain period of time based on continuous awareness and anticipation of movements by others and that establish control over one’s own behavior in time with changes in others’ movements). For such movements, voluntary and intentional motor output and sensorimotor feedback are critical (Torres et al., 2013). In this regard, drum playing, as one of the most common music behaviors (Matney, 2016), was selected because it can involve a repetitive or controlled pattern of movements at different levels in a different context. Furthermore, drum playing could provide immediate sensorimotor feedback depending on the level of involvement, control, and intentionality. Dyadic drum playing, in which two individuals coordinate their movements in time with each other while playing drums, would represent how a child with ASD connects to a partner and synchronizes his or her movement in response to the perceived movement of the partner in a musical context.

The purpose of this two-part study was to develop a rhythm-mediated intervention to improve the social motor skills (i.e., the skills to engage in joint action with others and to synchronize movements with those of others) of children with ASD and investigate preliminary efficacy. Given that incorporation of rhythmic aspects into an intervention for improving the social skills is a newer approach,
Study 1 aimed to confirm a positive relationship between dyadic drum playing and social skills and to identify essential intervention content before developing the rhythm-mediated music therapy intervention. Study 2 aimed to investigate the preliminary efficacy of the resultant intervention. The research questions for each study were as follows:

Study 1: What is the relationship between dyadic drum playing and social skills performance in children with and without ASD?

Study 2: Are there changes in the social skills of children with ASD after participating in the developed rhythm-mediated intervention?

**Study 1: Exploratory Factor Analysis of Dyadic Drum Playing and Social Skills**

**Methods**

**Participants**

Prior to enrolling participants, this study was reviewed and approved by the Institutional Review Board at Ewha Womans University (IRB No. 101–11). A total of 60 children, aged 11 to 16 years, were recruited for this study: 45 children with typical development (TD) and 15 children with high-functioning ASD. Through flyers posted in local schools and centers, we recruited children with TD from primary and middle schools, while participants with high-functioning ASD were recruited from schools and centers for individuals with developmental disabilities. Participants in the ASD group were diagnosed with ASD prior to the age of 3 and met criteria listed in the DSM-IV. Additional inclusion criteria were a Perceptual Reasoning Index (PRI) of 70 or higher on the Korean-Weschler Intelligence Scale for Children-IV (K-WISC-IV) and a score of 36 or lower on the Korean-Childhood Autism Rating Scale (K-CARS). Each of the participants and their guardians voluntarily agreed to participate in this study, with guardians providing informed consent.

**Design and Sample Size Justification**

We conducted an exploratory factor analysis as our main analysis method; it helps identify underlying dimensions of construct of
interest, particularly when we develop or assess theories or instruments. Previous studies have suggested that a minimum of 50 cases is adequate for factor analysis (Sapnas & Zeller, 2002). However, higher communality, which indicates the proportion of variability in each variable that can be explained by a factor, may reduce the influence of the sample size on the appropriateness of such analysis (MacCallum, Widaman, Zhang, & Hong, 1999). MacCallum et al. (1999) suggested that communality greater than .60 for all variables may justify a smaller sample size when using factor analysis. In this study, for the ASD group, the communality values were greater than .60 for all the variables except one (the communality in the variable of interpersonal synchronization with rhythmic cueing at a fast tempo was .55), which may support a smaller sample size than suggested.

Measures

The K-WISC-IV is a test of intelligence that has 15 subtests and is appropriate for children and adolescents aged 6–16 years. The test offers five indices: Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), Processing Speed Index (PSI), Working Memory Index (WMI), and Total Intelligence Index. In this study, we only used the PRI resulting from three subtests (Block Design, Picture Concepts, and Matrix Reasoning) because of its closer relationship to perception of untimed external information and limited demand on language ability.

The Korean-Social Skills Rating System (K-SSRS) measures the social skills of a child in social environments, such as school and home (Gresham & Elliott, 1990). The K-SSRS for elementary students and secondary school students targets children in grades 3 through 6 and grades 7 through 12. It comprises 30 items that are rated by guardians or teachers using a three-point Likert-type scale. It has three subscales: cooperation, assertion, and self-control. The Cronbach’s alpha coefficient for the K-SSRS has been estimated at .84 (total) and between .65 and .81 for the subscales, indicating a high level of internal consistency (Moon, 2003).

For assessing imitation skills, we selected 20 gestures: eight meaningful gestures and 12 meaningless gestures. For each meaningful and meaningless gesture category, intransitive gestures (i.e., actions without use of objects) and transitive (i.e., actions with
The use of objects) were considered for the tasks. Meaningful gestures included four social gestures (e.g., waving to say hello to another and hand gestures for the rock-paper-scissors game) and four gestures of imaginative object use (e.g., the gesture to pretend to brush one’s hair with a comb and to eat food with a spoon). With regard to meaningless gestures, we presented eight hand gestures (single and sequential gestures) and four actions on objects (e.g., a cup). A child’s attempt to imitate the modeled gestures was measured with a score of 2 if accurate imitation occurred. A score of 1 was recorded if the child initiated an imitative gesture but the gesture was not correct. A score of 0 was recorded if no imitative gesture was initiated by the child. Then we calculated a percentage score by dividing the obtained score by the possible total score of 40.

As a measure for recognizing facial expressions that convey intentions and emotions, Karolinska Directed Emotional Faces (KDEF) includes 490 photographs of faces conveying seven basic emotions (i.e., happy, sad, angry, afraid, disappointed, surprised, and neutral; Lundqvist, Flykt, & Ohman, 1998). For this study, we selected five pictures from each of the seven emotions that people had recognized most accurately in a previous study (Goeleven, de Raedt, Leyman, & Verschuere, 2008). During the test, participants named the emotion conveyed via the selected 35 pictures and we calculated the percentage of accurate responses.

For drum tapping tasks, each participant was instructed to tap on an electronic drum pad (Alesis PercPad, Alesis, USA) connected to a computer via a MIDI interface (AMON, Infrasonic, Korea). They tapped on the drum simultaneously with two mallets and matched (a) to the tempo of beats played using a MIDI-embedded metronome (i.e., rhythmic cueing), (b) to the tapping of an experimenter (which is hereafter referred to as interpersonal synchronization), and (c) to the tapping of an experimenter, paired with rhythmic cueing. The tempo was adjusted to three conditions: a moderate tempo (i.e., 100 bpm), fast tempi at 20% or more over 100 bpm (i.e., 120–140 bpm), and slow tempi at least 20% below 100 bpm (i.e., 60–80 bpm). Interpersonal synchronization conditions (i.e., with and without rhythmic cueing) are displayed in Figure 1. For these drum tapping tasks, the value of asynchrony (i.e., synchronization errors) was measured by calculating the difference between the onset timing of tapping and the onset timing of the cueing as
measured in milliseconds. An asynchrony score closer to zero indicates a smaller error in synchronization, which indicates a higher level of synchronization to rhythmic cueing or to the timing of another person’s drum tapping (Repp & Su, 2013).

**Procedures**

Following informed consent, the primary investigator administered measures to each participant individually in a quiet room of the recruiting school or community center. To measure PRI, the investigator administered three subtests of the K-WISC-IV, followed by administration of social skills measures and investigator-constructed drum tapping tasks. Prior to the study, we randomly assigned the order of social skills–related tests and drum tapping tasks. Each participant’s teacher completed the K-SSRS.

**Data Collection and Analysis**

Based on the obtained average scores of the social skills measures (i.e., self-control subscale in the K-SSRS, performance rate of the imitation tasks, and performance rate of the KDEF tasks) and the value of asynchrony, we conducted an exploratory factor analysis. The analysis aimed to analyze the correlation among variables and identify factors from the related variables. Bartlett’s test of sphericity and the Kaiser-Meyer-Olkin (KMO) were measured for sampling adequacy. In order to extract factors, we used principal-axis
factoring along with Varimax rotation. The number of factors was determined by examining the factor with an eigenvalue greater than 1.0. All statistical analyses were performed in SPSS Statistics 22.0. Once statistical analysis identified sets of variables possessing a strong relationship, the investigator interpreted the nature of the set and labeled it in order to propose how latent factors represent the conceptual relationship between dyadic drum playing and social skills.

Results

For Study 1, we recruited 60 children, and 52 participants were included in the final analysis (see Figure 2). Demographic information for participants is summarized in Table 1. The children with high-functioning ASD obtained an average of 28.1 (SD = 5.7; ranges 21–35) on K-CARS. Given that K-CARS ranged from 15 to 60 with 28 being the cutoff, and scores between 30 and 36 indicate mild to moderate autism, the range of scores showed that the participants exhibited mild symptoms of ASD. In addition, they obtained an average of 77.7 on the PRI in the K-WISC-IV.

![Flow diagram of participants through Study 1.](https://academic.oup.com/jmt/article-abstract/55/3/340/5076935)
Table 1

Demographic Information of Participants in Study 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>TD (n = 42)</th>
<th>ASD (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (M: F)</td>
<td>23: 19</td>
<td>10: 0</td>
</tr>
<tr>
<td>Age (years, M ± SD)</td>
<td>13.5 ± 0.8</td>
<td>13.4 ± 1.4</td>
</tr>
<tr>
<td>K-WISC PRI</td>
<td>95.0 ± 13.7</td>
<td>77.7 ± 20.2</td>
</tr>
<tr>
<td>K-CARS</td>
<td>–</td>
<td>28.1 ± 5.7</td>
</tr>
</tbody>
</table>


Social Skills Measures of Children with TD and High-Functioning ASD

Descriptive results of the social skills measures are displayed in Table 2. For the TD group, the K-SSRS scores were above the average levels for each of the three subscales (i.e., 11–19 for cooperation, 8–17 for assertion, and 10–18 for self-control on the elementary level of the SSRS). Participants with high-functioning ASD scored below the average levels for the subscales. For imitation tasks, while the TD group exhibited a 98.0% level of task performance, the ASD group exhibited an 89.4% level of task performance. When identifying the emotions in KDEF, the mean correct task performance rate was 75.4% for the TD group. Among the emotions presented, happiness was identified the most accurately, followed by surprise and no emotion/neutral. The least accurately identified emotion was fear. The ASD group exhibited an average correct performance rate of 50.4% on KDEF. They were most accurate in identifying the faces conveying happiness, followed by angry faces. They identified fearful faces the least accurately.

Asynchrony Measures During Matching to External Cues

The results of asynchrony measures are displayed in Table 3. Given the discrepancy in the number of females in each group (19 females in the TD group and none in the ASD group), we compared the asynchrony measure during tapping to rhythmic cueing at 100 bpm between males and females in the TD group. There were no significant differences between the two groups in terms of the asynchrony measure (p = .689), indicating that the inclusion of
females in the TD group did not affect the asynchrony measure. For the TD group, there was smaller asynchrony during tapping to rhythmic cueing compared to interpersonal synchronization without RC. For the two types of interpersonal synchronization tasks (i.e., with and without RC), smaller asynchrony was found with the use of rhythmic cueing, indicating increased attempts to adjust to cueing. With regard to the tempo of interpersonal synchronization, the highest asynchrony values were observed at slower tempi. The ASD group showed similar patterns of asynchrony measures under tapping conditions, compared to the TD group. The ASD participants tended to show the smallest asynchrony during tapping to rhythmic cueing and the greatest asynchrony during interpersonal synchronization without rhythmic cueing. With the use of rhythmic cueing, asynchrony measures during interpersonal synchronization tended to become smaller. With regard to the tempo condition, higher asynchrony measures were measured at slower tempi.

![Table 2](https://academic.oup.com/jmt/article-abstract/55/3/340/5076935)

**Table 2**

*Study 1 Results: Social Skills–Related Test Scores for the TD and ASD Groups*

<table>
<thead>
<tr>
<th>Social skills test</th>
<th>TD (n = 42)</th>
<th>ASD (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M ± SD</td>
<td>M ± SD</td>
</tr>
<tr>
<td>K-SSRS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooperation</td>
<td>16.9 ± 4.4</td>
<td>9.8 ± 5.6</td>
</tr>
<tr>
<td>Assertion</td>
<td>17.4 ± 3.2</td>
<td>6.9 ± 6.2</td>
</tr>
<tr>
<td>Self-control</td>
<td>18.1 ± 2.5</td>
<td>6.4 ± 5.4</td>
</tr>
<tr>
<td>Total</td>
<td>52.4 ± 9.2</td>
<td>23.1 ± 16.0</td>
</tr>
<tr>
<td>Imitation</td>
<td>98.0 ± 3.0</td>
<td>89.4 ± 10.0</td>
</tr>
<tr>
<td>KDEF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Happy</td>
<td>100.0 ± 0.0</td>
<td>86.1 ± 33.3</td>
</tr>
<tr>
<td>Sad</td>
<td>65.5 ± 24.7</td>
<td>47.2 ± 26.4</td>
</tr>
<tr>
<td>Surprised</td>
<td>95.8 ± 9.4</td>
<td>66.7 ± 30.6</td>
</tr>
<tr>
<td>Fearful</td>
<td>23.2 ± 21.7</td>
<td>13.9 ± 13.2</td>
</tr>
<tr>
<td>Angry</td>
<td>81.0 ± 19.8</td>
<td>77.8 ± 29.2</td>
</tr>
<tr>
<td>Disgusted</td>
<td>66.7 ± 22.2</td>
<td>22.2 ± 23.2</td>
</tr>
<tr>
<td>Neutral</td>
<td>95.8 ± 8.8</td>
<td>38.9 ± 37.7</td>
</tr>
<tr>
<td>Total</td>
<td>75.4 ± 8.8</td>
<td>50.4 ± 14.1</td>
</tr>
</tbody>
</table>

Factor Analysis of Dyadic Drum Playing as a Social Skills Measure

We conducted exploratory factor analysis to identify the underlying structures among each set of variables based on the relationships among the measured variables. The KMO measure of sampling adequacy was greater than 0.6, supporting that factor analysis was appropriate for the data. Bartlett’s sphericity measure was below the recommended value of 0.05, also suggesting that factor analysis was acceptable for this study. Principal-axis factoring extracted three and four factors for the TD and ASD groups, which explained 61.7% (TD group) and 82.0% (ASD group) of the variance.

For the TD group, three factors were generated. Four variables loaded on Factor 1: the self-control subscale in K-SSRS, the task performance of imitation, KDEF task, and asynchrony during interpersonal synchronization at 100 bpm. Six variables loaded on Factor 2. Among the asynchrony measures collected during drum tapping tasks, most of the measures were included, except interpersonal synchronization with and without rhythmic cueing at a fast tempo. Finally, the two variables loaded on Factor 3 included interpersonal synchronization with and without rhythmic cueing at a fast tempo.

For the ASD group, four factors were generated. For Factor 1, two variables loaded: the self-control subscale of the K-SSRS and

<table>
<thead>
<tr>
<th>Subtask</th>
<th>TD (n = 42) M ± SD</th>
<th>ASD (n = 10) M ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tapping to RC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slow 100 bpm</td>
<td>–13 ± 51</td>
<td>31 ± 22</td>
</tr>
<tr>
<td>Fast 100 bpm</td>
<td>–25 ± 44</td>
<td>–33 ± 40</td>
</tr>
<tr>
<td>Fast Slow</td>
<td>41 ± 116</td>
<td>9 ± 30</td>
</tr>
<tr>
<td>Fast Fast</td>
<td>–35 ± 38</td>
<td>–35 ± 24</td>
</tr>
<tr>
<td>Interpersonal sync</td>
<td>82 ± 65</td>
<td>36 ± 59</td>
</tr>
<tr>
<td>200 bpm</td>
<td>–20 ± 47</td>
<td>120 ± 210</td>
</tr>
<tr>
<td>Fast Slow</td>
<td>120 ± 210</td>
<td>76 ± 104</td>
</tr>
<tr>
<td>Fast Fast</td>
<td>–45 ± 204</td>
<td>–45 ± 204</td>
</tr>
<tr>
<td>Interpersonal sync with RC</td>
<td>54 ± 61</td>
<td>12 ± 45</td>
</tr>
<tr>
<td>200 bpm</td>
<td>12 ± 45</td>
<td>54 ± 53</td>
</tr>
<tr>
<td>Fast Slow</td>
<td>54 ± 53</td>
<td>46 ± 35</td>
</tr>
<tr>
<td>Fast Fast</td>
<td>12 ± 42</td>
<td>12 ± 42</td>
</tr>
</tbody>
</table>

Note. RC: rhythmic cueing; Sync: synchronization. The value of asynchrony was measured as milliseconds.

Table 3

Study I Results: Asynchrony During Drum Tapping Tasks in the TD and ASD Groups

<table>
<thead>
<tr>
<th>Subtask</th>
<th>TD (n = 42)</th>
<th>ASD (n = 10)</th>
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<tr>
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Note. RC: rhythmic cueing; Sync: synchronization. The value of asynchrony was measured as milliseconds.
asynchrony during tapping to rhythmic cueing at a slow tempo. Three variables loaded on Factor 2: task performance rates of imitation and KDEF task, and asynchrony during interpersonal synchronization with the presence of rhythmic cueing at a slow tempo. Furthermore, three variables loaded on Factor 3: asynchrony during tapping to rhythmic cueing at 100 bpm and interpersonal synchronization with rhythmic cueing in two tempo conditions (i.e., 100 bpm and at a fast tempo). Finally, four variables loaded on Factor 4: tapping to rhythmic cueing at a fast tempo and interpersonal synchronization without rhythmic cueing at all three tempo conditions.

Interpretation and Labeling of Factors

A total of three factors were generated for the TD group and a total of four factors for the ASD group. Analysis of variables loaded on the common factor led to the generation of related agents. For the TD group, a total of three factors were extracted (see Figure 3) and we then labeled them. The four variables loaded on Factor 1 (i.e., the self-control subscale of the K-SSRS, the performance rate of imitation and KDEF tasks, and asynchrony during interpersonal synchronization at 100 bpm) involved the perception of bodily performance and expressions by others. Also, these were related to the ability to adjust behavior responses via bodily simulation or joint action within a shared experience with others. Accordingly, Factor 1 was labeled Embodied Intersubjectivity.

In the figure, the number points to the factor loading for each variable, which indicates how much of a factor is accounted for by a particular variable. If the absolute value is closer to 1, within the range of –1 to 1, the strength of the relationship between the factor and the variable becomes greater. A negative value indicates that the direction of influence that the factor has on the variable is the opposite. In terms of negative factor loading values for some variables, the opposite direction of the influence that the factor has on the self-control subscale in the K-SSRS versus the performance of imitation and KDEF tasks may be attributed to the fact that the type of bodily responses representative of the expected interpersonal experiences could be opposite: while self-control is related to inhibition of behaviors, the other two social behaviors are associated with execution of behaviors.
The variables loaded on Factor 2 were tapping to rhythmic cueing in all three tempo conditions, interpersonal synchronization at a slow tempo, and interpersonal synchronization with rhythmic cueing at slow and moderate tempi. These were related to the control of internal behavioral patterns in relation to perceived information or action outcomes within an expected time referent. Thus, Factor 2 was labeled *Motor Representation*.

Finally, two measures loaded on Factor 3: interpersonal synchronization with and without rhythmic cueing at a fast tempo. During motor performance with changes in the period of external auditory cueing, an individual adjusts his or her movement (or internal timekeeper) to the newly calculated time interval. While motor commands at a slower tempo require increased cognitive-perceptual processing of timing (Mastrokalou & Hatziharistos, 2007), a faster tempo is associated with increased demand for motor planning (de Castelnau, Albaret, Chaix, & Zanone, 2008). This explains why variables associated with rhythmic cueing at a faster tempo were represented by a latent factor separate from the factor related to the variables at a slower tempo in this study. Thus,
the latent factor associated with interpersonal synchronization at a faster tempo was labeled Anticipatory Adjustment.

For the ASD group, four factors were labeled (see Figure 4). Two variables loaded on Factor 1: the self-control subscale of the K-SSRS and asynchrony during tapping to rhythmic cueing at a slow tempo. While these measured variables were related to the ability to select and coordinate one’s own behaviors in response to the environment, they required relatively less understanding of a social partner’s thoughts, intentions, and emotions in real time. Accordingly, Factor 1 was labeled Self-Regulation as the construct of adjusting behavior responses via intentional inhibition or imitation to achieve stable intrapersonal bodily states (Hofman, Schmeichel, & Baddeley, 2012).

For Factor 2, three variables loaded: task performance rates of the imitation task and KDEF (i.e., facial expression identification tasks) and asynchrony during interpersonal synchronization with the presence of rhythmic cueing at a slow tempo. As the imitation and KDEF tasks required the identification of bodily responses (behaviors to be imitated or facial expressions) and intentions of others based on their actions, this factor was labeled Embodied Intersubjectivity.
Three variables, all of which were related to the provision of rhythmic cueing (i.e., predictable time referent), loaded on Factor 3: asynchrony variables during tapping to rhythmic cueing at 100 bpm and interpersonal synchronization with the presence of rhythmic cueing at 100 bpm and a fast tempo. The task of tapping on the drum in terms of such fixed intervals, particularly at a moderate tempo, requires more of an ability to predict, prepare, and generate behavioral patterns in relation to the expected action outcomes. Thus, this latent factor was labeled Motor Representation.

Finally, the four variables loading onto Factor 4 were tapping to rhythmic cueing at a fast tempo and interpersonal synchronization without rhythmic cueing in all three tempo conditions (100 bpm and a slow and a fast tempo). Tapping on the drum in accordance with changes in a timing referent involves the ability to attend to and process the upcoming information and organize one’s own movement within such adjusted timing framework. Thus, this factor was labeled Anticipatory Adjustment.

Discussion

In sum, the results of Study 1 indicate that dyadic drum playing is associated with social skills-related factors. Embodied Intersubjectivity, Motor Representation, and Anticipatory Adjustment were the factors underlying dyadic drum playing and social skills in both groups. The underlying construct Self-Regulation was unique to the ASD group. This finding suggests that self-control is an independent and precedent factor for developing the abilities of individuals with ASD to manage their behaviors in relationship with perceived input from the environment and others. It is consistent with the assertion that spontaneous bodily experiences precede social awareness in individuals with ASD (Mundy, Gwaltney, & Henderson, 2010), which gives rise to the need for intentional engagement in controlled movements at the initial stage of interventions for social skills development with this population.

Furthermore, this study demonstrated that the relationships between drum playing and social skills differed between the TD and ASD groups. Among the TD group, all measured social skills were found to be related to an interpersonal synchronization task at 100 bpm while being represented by the same latent factor. Unlike the
TD group, social skills measures in the ASD group (i.e., imitation and KDEF measures) were correlated to interpersonal synchronization with rhythmic cueing at a slow tempo. This indicates that while the task to coordinate movement at a moderate tempo may involve social information for children without ASD, the presence of rhythmic cueing and tempo adjustment involve a greater ability to coordinate one’s movement in concert with social information processing in children with ASD. In these children, attempts to match the slow-paced movements of another person were found to require a greater ability to time perceived movement, which could be facilitated with the use of rhythmic cueing.

These results support the idea that for individuals with ASD, motor control with the use of rhythmic cueing at different tempi may be developed or addressed with the same mechanism as the ability to understand the motor information of others and integrate that information into one’s own behavior. In addition, it resulted in the identification of two aspects that could directly inform such intervention efforts: the importance of rhythmic cueing and the use of a slower tempo during dyadic drum playing.

Study 2: Development of a Rhythm-Mediated Intervention to Improve Social Skills in Children with ASD

In Study 1, we demonstrated the factors underlying dyadic drum playing and social skills. Such findings resulted in the identification of intervention components to be targeted for the social skills of children with ASD in the context of dyadic drum playing and rhythmic cueing. Study 2 aimed to construct and implement such a rhythm-mediated intervention and validate its preliminary efficacy. The research question for this study was the following: Are there changes in the social skills of children with ASD after participating in the developed rhythm-mediated intervention?

Methods

Participants

All of the relevant procedures and ethical issues were reviewed and approved by the Institutional Review Board at Ewha Womans University (IRB No. 101–11). A total of nine children with ASD
were recruited separately from Study 1. They were from primary and middle schools and centers for individuals with developmental disabilities. They were screened for a medical diagnosis of ASD and reported no psychiatric or neurological comorbid disorders. A K-CARS score was also obtained from each participant. A written informed consent was obtained from each participant and his or her caregiver.

**Materials**

**Musical Instruments.** With regard to the selection of instruments, different types of instruments in terms of size, timbre, and playing method were considered to reflect children’s varied interests and elicit their engagement in the intervention. In addition, the selection of instruments took into consideration the requisite involvement of gross movements (e.g., drums such as the bongo or tubano played in a standing position, temple block played from a standing position, and bass xylophone played with the use of heavy mallets) and bimanual coordination (e.g., claves, djembes, and barred instruments with two mallets).

**Music and Rhythmic Cueing.** Musical stimuli were constructed to provide a rhythmic structure for the children’s movements. In order to enable rhythm to primarily mediate the target movements, a four-beat rhythm pattern and repetitive melodic pattern, instead of developing the melodic motive, were primarily used. For the purpose of facilitating the children to instantly shift their attention toward a signal and maintain it, the use of a constantly changing but melodic pattern with the application of intervals of greater than a fourth or fifth (e.g., the notes C and F or C and G) between successive notes was considered. Examples of how a rhythmic structure was provided via live accompaniment are displayed in Figure 5. When additional rhythmic cueing was needed, a metronome or rhythmic pattern embedded in an electronic device (e.g., electronic keyboard) was also used.

**Intervention.** Based on the results of Study 1, the rhythm-mediated intervention was developed to incorporate dyadic drum playing, rhythmic cueing, and tempo adjustment. Accordingly, the intervention consisted of three stages: engagement, interpersonal coordination, and modulation (see Figure 6). First, engagement is the initial process of facilitating a child’s awareness of a
social partner (i.e., a music therapist) and of the environment and engagement with musical stimuli or activities. It is based on previous research (Mundy et al., 2010) and the Study 1 results that demonstrate how self-regulatory experiences precede the awareness of others or the environment in ASD. For this, a child is given instruments, and a music therapist follows the child’s lead by imitating the initiated movements via identical action or by musically matching the features (e.g., speed or intensity) of involved movements or the energy level of the child. Once a child maintains engagement with the musical stimuli, based on the assessment of the speed or intensity of the child’s rhythmic movement, rhythmic cueing is provided to support the child’s maintenance of his or her controlled movement via musical exploration.

The second stage is interpersonal coordination, which is embodied in synchronous movements. When targeting the interplay between social and motor development in individuals with ASD, the intervention focus needs to be on deficiencies in motor coordination, particularly anticipatory control (Schmitz, Martineau, Barthélémy, & Assaiante, 2003). Accordingly, facilitating the building of internal representations of external information (i.e., modeled or initiated behavior for the purpose of social interaction) is considered critical. For this stage, target movements

Figure 5.
Example of music used for playing claves.
are selected from the child’s repertoire. The therapist models a part of or variation of the target movements to be imitated by the child. The cooperative movements (i.e., the movements that are implemented in cooperation between the child and the therapist, such as holding or carrying the object together) can also be used. Once a child is able to engage in the identical movement with the therapist, the child is facilitated to maintain the movement in time with the therapist. At this stage, rhythmic cueing via the provision of a rhythmic structure based on isochronous beats is continuously provided, so that the child can successfully construct and execute target movements within the predictable temporal structure.

The final stage, adaptive adjustment, maximizes the motor control in response to the modulated tempo or complex sequences of the targeted synchronized movements. Research supports that the disruption of synchronous movements that has already been established can play a role in enhancing the recognition of self and other (Mundy et al., 2010). As such, eliciting synchronous adjustment to a movement by changing the timing and intensity of the movement is considered to facilitate discrimination of self from others and continuous attending to others (Behrends et al., 2012). For this component, the tempo of movement and rhythmic cueing is modulated. Based on the results of Study 1 in which children with ASD showed increased difficulty accurately synchronizing but rather engaged in social skills at a slower tempo, the initial tempo must be moderate to fast to elicit more successful engagement.

**Figure 6.** Components of the rhythm-mediated intervention. MT refers to a music therapist who implements the intervention and participates in the therapeutic environment as a social partner of a child with ASD.
from the children. Then, the tempo can be modulated to a slower tempo by changing the intervals of cueing. Complex sequences of movements can also be used by combining the single movement within the child’s repertoire. A combination of different hand gestures or multilimb movement sequences can also be utilized.

The validity of the resultant intervention was assessed by a total of six certified music therapists with a mean age of 37.0 years (SD = 6.0), clinical experience of 10.7 years (SD = 7.1), and clinical experience with individuals with ASD of 7.7 years (SD = 4.2). The Modified Scale of Treatment Perception (Berger, Manston, & Ingersoll, 2016) was used for testing validity. The measure included four categories: (a) clinical relevance of the goal to the social skills of children with ASD, (b) adequacy of the procedures implemented in addressing the needs of children with ASD, (c) importance of the outcomes, and (d) acceptability of the intervention. Music therapists rated each of 20 items (five items for each category) from 1 (strongly disagree) to 5 (strongly agree), with their mean rating being 21.5 (SD = 1.9). The content validity index (CVI), calculated as the proportion of those who rated the item with a score of 4 or 5 (Polit & Beck, 2006), ranged from .90 to 1.00 with an average of .92. Given that a CVI of .80 or higher is considered acceptable, these results indicate that the intervention is sufficiently valid.

Procedures. Each participant received a total of eight 30-minute individual sessions. The sessions were conducted in a quiet place within the school or community center where each participant was recruited. The primary investigator, a board-certified music therapist, implemented the intervention. The duration of each stage was determined depending on the level of each child’s participation and ability to spontaneously maintain attention and involvement in dyadic experiences. For initial sessions, only the first and second stages were sequentially implemented. Within a single session, the duration of the second stage gradually increased. At the middle point of the program (from the fourth session), the implementation of the third stage was determined depending on whether a child could maintain his or her involvement in dyadic experiences. Afterward, all of the three stages were included within a single session, and the duration of higher stages gradually increased. Although the sequence of implementation for each stage was
maintained in general, if a child showed difficulties in maintaining dyadic involvement for a certain period of time (e.g., the second and third stages), the activities for engagement and interpersonal coordination (or adaptive adjustment) were rotated. At pretest and posttest, social skills measures and drum tapping tasks were administered in the same place in which the child received the intervention.

**Measures.** For social skills measures, K-SSRS and imitation tasks were administered to each participant. For the K-SSRS, the guardian or teacher of each participant was instructed to rate the child’s social skills as observed at home or at school according to the given scale. During imitation tasks, each participant was instructed to imitate 20 gestures in total, which included eight meaningful (e.g., waving to say hello to another) and 12 meaningless gestures (e.g., simple hand gestures and gestures with the use of objects) as modeled by a tester (i.e., the investigator).

In addition, we obtained asynchrony measures during drum tapping tasks. As in Study 1, the tasks of tapping to rhythmic cueing and tapping to another person with and without the provision of rhythmic cueing were presented to each participant using the electronic drum connected to a computer via MIDI. In order to measure how accurately the child matched to the external timing (either rhythmic cueing or the timing of another person, which was the investigator), the values of asynchrony (ms) were measured by calculating the difference between the onset of a participant’s tapping and an external stimulus (i.e., rhythmic cueing or the investigator’s tapping).

To analyze behavioral changes throughout the sessions, video recordings were taken from sessions 2, 4, 6, and 8. The investigator and a certified music therapist who had over 5 years of clinical experience with children with ASD independently coded the occurrence of behaviors. Prior to participating in the evaluation procession, the coder was trained in terms of the definition of the target behaviors (see Table 4) and the coding procedures. Five-minute clips from at least 10 minutes after the start were selected from each target session and separated into 5-second intervals. The trained coder was presented with the video clips in a predetermined random order and was blind to which sessions the video clips came from. During each of a total 60 intervals, whether a
target behavior occurred was marked. We then measured the percentage of intervals in which the target behavior was documented.

Social validity was measured by asking each participant’s guardian to rate their child’s social skills according to a given scale at posttest. The scale was constructed with regard to the perceived effectiveness of the intervention, perceived acceptability of the intervention, and willingness to participate in the intervention further. Each of the three subcategories consisted of five items rated 1 (strongly disagree) to 5 (strongly agree). Among the guardians, individuals who agreed to give their opinions on the intervention were also interviewed with regard to its importance and relevance and limitations that they experienced.

**Data Collection and Analysis.** The scores of the social skills measures (i.e., K-SSRS and imitation tasks) and the values of asynchrony during drum tapping tasks at pretest and posttest were analyzed using a Wilcoxon signed-rank test. With regard to behavioral coding, the percent of intervals in which predefined target behaviors occurred were collected from sessions 2, 4, 6, and 8 and analyzed in terms of the trend in changes in behavioral occurrence. Intraclass correlation coefficients were calculated for the data collected from behavioral observation by both the investigator and coder to determine the interrater reliability.

**Results**

In Study 2, nine children with ASD were recruited, but one withdrew from the study. Therefore, eight children with ASD participated in the rhythm-mediated intervention for a total of eight sessions. All of the participants were male, and their mean age

<table>
<thead>
<tr>
<th>Target behavior</th>
<th>Operational definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye gaze</td>
<td>Looking at or shifting eye gaze toward a partner</td>
</tr>
<tr>
<td>Engagement in joint action</td>
<td>Involvement in the same movement simultaneously with a partner</td>
</tr>
<tr>
<td>Synchronous movement</td>
<td>Involvement in a movement at the same tempo as a partner</td>
</tr>
</tbody>
</table>
The mean score of K-CARS was 39.5 (SD = 6.4; ranging from 35 to 49). Changes in social skills measures and asynchrony measures during drum tapping tasks after participation in the intervention and the occurrence of predefined target behaviors during sessions were analyzed.

**Changes in Social Skills Measures.** With regard to K-SSRS, the results of a Wilcoxon signed-rank test showed that significant increases were observed in the cooperation and self-control sub-skill scores and total score. Also, children with ASD showed slightly, but not significantly, increased imitation performance at posttest, compared to pretest (see Table 5).

**Changes in Asynchrony During Drum Tapping Tasks.** The results of changes in the asynchrony measures during drum tapping tasks are displayed in Table 6 and Figure 7. For the task of tapping to rhythmic cueing without the presence of another person, decreased asynchrony (i.e., increased accuracy of synchronization) was observed in the 100 bpm and fast tempo conditions. For the interpersonal synchronization task without rhythmic cueing, the greatest decrease was shown in the slow and fast tempo conditions. During the task of interpersonal synchronization with the provision of rhythmic cueing, decreased asynchrony was observed in all three tempo conditions; the greatest change was observed in the fast tempo condition. Despite the tendency of decreased synchronization errors, the results of a Wilcoxon signed-rank test showed that such changes did not reach statistical significance.

**Changes in Observed Behaviors During Sessions.** In terms of behavioral changes in eye gaze, engagement in joint action, and synchronous movement observed during sessions (sessions 2, 4, 6, and 8), the results are displayed in Figure 8. Interrater reliability was 90.1%. Comparison of the occurrence of the target behaviors between the second and eighth sessions showed that children with ASD demonstrated increases in all behaviors, and the greatest increase was observed with engagement in joint action. More drastic increases in the presence of target behaviors tended to occur between the second and fourth sessions and between the sixth and eighth sessions. Between the fourth and sixth sessions, the rate of changes remained at a stable level.

**Social Validity of the Intervention.** After participation in the study, guardians of the children with ASD rated the social validity of the intervention. With scores of 4 and 5 indicating responses of
“agree” and “totally agree,” respectively, the mean rating was 3.6 for effectiveness, 4.4 for acceptability, and 4.4 for willingness to participate. The analysis of individual items showed that the general rating of the intervention’s effectiveness was high, but the immediacy of the effectiveness was rated lowest among the category. The level of perceived acceptability of the intervention and willingness to participate in the intervention again in the future were both high: the mean ratings for all items were 4.4 in the category of acceptability and ranged from 3.8 to 4.6 in the category of willingness to participate.

Analysis of the feedback from the guardians after participation in this intervention showed that most of them found the intervention was appropriate for their children and that they were likely

<table>
<thead>
<tr>
<th>Measure</th>
<th>Pretest (M ± SD)</th>
<th>Posttest (M ± SD)</th>
<th>Z</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>K-SSRS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooperation</td>
<td>7.4 ± 1.9</td>
<td>10.9 ± 2.4</td>
<td>-1.992</td>
<td>.046*</td>
</tr>
<tr>
<td>Assertion</td>
<td>8.9 ± 1.5</td>
<td>10.0 ± 1.6</td>
<td>-1.483</td>
<td>.138</td>
</tr>
<tr>
<td>Self-control</td>
<td>9.4 ± 2.1</td>
<td>12.6 ± 1.8</td>
<td>-2.201</td>
<td>.028*</td>
</tr>
<tr>
<td>Total</td>
<td>25.7 ± 4.8</td>
<td>33.5 ± 4.6</td>
<td>-2.201</td>
<td>.028*</td>
</tr>
<tr>
<td>Imitation (%)</td>
<td>35.8 ± 39.1</td>
<td>36.7 ± 39.0</td>
<td>-1.604</td>
<td>.109</td>
</tr>
</tbody>
</table>

*p < .05.

<table>
<thead>
<tr>
<th>Tempo condition</th>
<th>Slow</th>
<th></th>
<th>100 bpm</th>
<th></th>
<th>Fast</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tapping to RC</td>
<td>-13 ± 31</td>
<td>-23 ± 64</td>
<td>124 ± 108</td>
<td>41 ± 148</td>
<td>107 ± 69</td>
<td>-43 ± 49</td>
</tr>
<tr>
<td>Interpersonal sync</td>
<td>124 ± 108</td>
<td>1 ± 104</td>
<td>41 ± 82</td>
<td>85 ± 20</td>
<td>-72 ± 212</td>
<td>53 ± 93</td>
</tr>
<tr>
<td>Interpersonal sync with RC</td>
<td>107 ± 69</td>
<td>87 ± 49</td>
<td>-43 ± 115</td>
<td>33 ± 9</td>
<td>-107 ± 29</td>
<td>31 ± 34</td>
</tr>
</tbody>
</table>

*Note. RC: rhythmic cueing; Sync: synchronization.*
Figure 7.
Changes in asynchrony during drum tapping tasks. From the top to bottom, each panel represents changes for the task of tapping to rhythmic cueing (Panel A), interpersonal synchronization without rhythmic cueing (Panel B), and interpersonal synchronization with rhythmic cueing (Panel C).
to participate in this intervention in the future. In addition, the guardians of participants who showed more severe autistic symptoms and lower levels of social skills development reported more immediate positive effects on their children’s motor coordination–related skills and social relationships. One of the guardians reported that her child showed drastic increases in attending to others’ actions and attempting to imitate their behaviors while his stereotyped behaviors such as wandering and hand flapping decreased. Guardians of participants with more mild autistic symptoms tended to point out that their children enjoyed music more after the intervention. They also showed relatively lower ratings of the immediate outcomes on the social skills and the potential for maintaining changes in the social skills. Two of those guardians commented on the need for more direct changes in social behavior and communication skills. They expressed that they had wanted to observe the changes in the social skills in their children’s relationship with peers.

**Discussion**

The results of Study 2 demonstrated that the social skills of children with ASD improved after receiving the rhythm-mediated music therapy intervention, as evidenced by changes in the K-SSRS,
imitation performance rate, and synchronization errors when tapping to the timing of a partner’s tapping at slow and fast tempi. Among the K-SSRS subscales rated by the guardians or teachers of the children, significant changes were observed in cooperation and self-control, which was directly associated with what was targeted in the context of the intervention. This indicates that a rhythm-mediated intervention can target a specific social skill effectively and that such influence can be generalized to a nonmusical social environment.

The tendency of decreased asynchrony measures after intervention supports that the ability to sustain attention to motor information from the behavior of another person in a dyadic situation and integrate perceived information into actions in response to a person could be addressed in this intervention. More specifically, greater decreases in asynchrony measures at adjusted tempo conditions (i.e., at a slower or faster tempo) indicate that intervention-specific effects may be related to the more complex processing of timing and represented motions induced by tempo changes in external stimulation, which involve sustained attention to continuously provided temporal information including social partners’ movements.

Furthermore, visual analysis of the behavior changes observed during the intervention sessions demonstrated that the occurrence of target behaviors increased across the sessions. An interesting finding to note was that greater changes occurred between the second and fourth sessions and between the sixth and eighth sessions. Such results suggest that while the musical and rhythmic structure may immediately facilitate the initial processing of attending to joint action and engagement in the action, long-term intervention is still needed for the maintenance of such initiated action in response to others and the environment.

**General Discussion and Implications**

This two-part study aimed to identify how social skills and aspects of dyadic drum playing are interrelated (Study 1) and thereafter develop a rhythm-mediated intervention based on the understanding of how such aspects can be used to improve the social skills of children with ASD (Study 2).
Exploratory factor analysis results of Study 1 showed that dyadic drum playing was related to social skills, which aligns with previous research on the interplay between motor and social skills (Fitzpatrick et al., 2013; Koehne et al., 2016). As the ability to anticipate and execute targeted behaviors in time with external information is critical for addressing the social issues of individuals with ASD (Torres et al., 2013), rhythmic playing behavior in response to perceived information from others can involve social skills for this population. Furthermore, the effect of rhythmic cueing on the differential involvement of social skills indicates that the provision of predictable information can be an adaptive strategy for individuals with ASD to properly control their behaviors in association with interaction with others and the environment.

Also, this study explains the underlying factors associated with targeted skills and how specific nonmusical skills can be converted to musical behavior, which formed the basis for Study 2. Based on such theoretical and clinical evidence, the effects of rhythmic cueing on nonmusical responses (i.e., social motor skills) were constructed into an intervention. This attempt aligns with evidence-based practice, while validating the processes from conceptualizing the mechanism behind target goal areas and designing an intervention approach to evaluating the effectiveness of such a clinical application. The successful link among substudies makes the results of this study more encouraging, while bridging a newly evidenced theoretical framework and clinical implementation.

This study supports the applicability of the structured rhythm-mediated intervention for children with ASD. In particular, this study corroborated the stepwise approach to motor coordination in response to changes in the level of external cueing within a dyadic relationship. The sequence of engagement, interpersonal coordination, and adaptive adjustment could be successfully applied to children with ASD. Based on these results, music therapy practitioners may be able to apply the intervention for motor control of children with ASD who show a low level of sensorimotor and/or social skills development. This study also highlights how practitioners need to approach such intervention in a successive way. For example, they could start with exploration with rhythmic movement and then elicit joint engagement in the rhythmic movements with a partner (e.g., music therapist or another client in a
music therapy group). More importantly, they must consider the adjustment of the tempo and the use of the rhythmic structure by providing rhythmic cueing or regularly paced music.

As an innovative approach, this study supports how rhythm can be effectively incorporated into interventions for improving the social skills of children with ASD. This approach sets forth a new paradigm for understanding and intervening with this population by facilitating motor control processes in a social context with the evidenced use of rhythmic cueing. It is congruent with changes in perspective that expand the focus of interventions from cognitive to motor dimensions in social skills development. Such a paradigm shift highlights the need to target lower levels of sensorimotor processing, including coordinating one’s own behavior in time, in relation to the external world (Knoblich & Sebanz, 2008; Trainor & Cirelli, 2015). Furthermore, the validation of intervention in terms of its applicability and effectiveness corroborates the fact that this newer music therapy approach to social skills development of children with ASD can be effectively replicated and referenced by music therapy professionals while affording them broadened perspectives on ASD as a neurodevelopmental disorder.

**Limitations and Suggestions for Future Research**

Although the findings of this study are promising, they should be interpreted with caution, particularly in Study 1 with the ASD group. While previous studies point to the importance of adequate sample size when conducting exploratory factor analysis (Sapnas & Zeller, 2002), the measured high commonalities may justify this study’s smaller sample size (MacCallum et al., 1999). Although the results of this study present how drum playing with populations with TD and ASD can be related to social skills and how these two groups differ from each other, further studies with larger sample size are needed to corroborate the underlying factors. The outcomes and effectiveness of the intervention must also be interpreted with caution, since this study used a design without a control group and with a small sample size. Further studies with a controlled design and longer periods of intervention are needed to generalize the intervention outcomes across the population.

Although this study targeted specific social skills (i.e., involved in synchronous movement or imitative movements) at the
sensorimotor level, as a preliminary investigation of the developed intervention, it did not consider the variability of autism symptoms or developmental level across participants. Analysis of feedback from the participants’ guardians in terms of effectiveness and acceptability of the intervention highlighted this limitation. While the currently developed intervention could produce more immediate and direct effects on the social needs of children with severe autistic symptoms, children with mild symptoms showed relatively lower levels of progress in terms of immediacy and degree of intervention outcomes. This suggests the inclusion of more complex and advanced levels of dyadic drum playing for children who show relatively lesser needs at the sensorimotor level. In consideration of the nature of the disorder showing a high degree of individual differences, further studies are needed to control for the level of social and motor development and the degree of disorder-specific behavioral symptoms.

In addition, this study targeted primarily bimanual coordination, involving upper limbs during instrument playing. Although this effectively confirms the effects of the intervention in more systematic and controlled conditions, it has limitations in reflecting the type and level of the motor development of each participant. Given that the type and level of movement involves different levels of motor and cognitive functioning, more specified guidelines for considering and selecting target movements need to be determined. In addition, factors found to influence interpersonal synchronization such as the type of movement, the intentionality of the target movements (intentional versus spontaneous), and type of feedback (Repp & Su, 2013) should be considered in implementing the intervention in further studies.

This study was also based on the dyadic relationship between a child and a therapist (i.e., an adult). Outcomes of the intervention were evaluated in terms of this child-adult relationship. Given that relationships with peers are also critical for children with ASD, further studies will need to examine whether the effects of long-term implementation of the rhythm-mediated intervention can be generalized to peer interaction. Also, when intervening with children with ASD, given the role of peers who can model appropriate social skills, the inclusion of a peer in the intervention in a small-group format should be considered.
In conclusion, the current study supports the potential benefits of the rhythm-mediated intervention for improving the social skills of children with ASD and is worth continued study. This study presents the structured framework with regard to the use of rhythmic cueing for the social domain of children with ASD, which makes this area of research a promising avenue for further research. Furthermore, it contributes to enhancing the competency of professionals who work with this population and expands the evidence-based practice in the clinical field of music therapy.

Acknowledgment

This study was completed in the primary investigator’s partial fulfillment of the degree of Doctor of Philosophy at Ewha Womans University. The full dissertation is available through Ewha Thesis at http://lib.ewha.ac.kr/search/media/url/CAT000001901505.

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