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A comparison of the effects of rhythm and robotic interventions on repetitive behaviors and affective states of children with Autism Spectrum Disorder (ASD)

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Abstract

Repetitive behaviors and poor affect regulation are commonly seen in children with Autism Spectrum Disorder (ASD). We compared the effects of two novel interventions - rhythm and robotic therapies, with those of a standard-of-care intervention, on the repetitive behaviors and affective states of 36 children with ASD between 5 and 12 years using a randomized controlled trial design. We coded for frequencies of sensory, negative, and stereotyped behaviors and the duration of positive, negative, and interested affective states in children during early, mid, and late training sessions. In terms of repetitive behaviors, in the early session, the rhythm and robot groups engaged in greater negative behaviors, whereas the comparison group engaged in greater sensory behaviors. With training, the rhythm group reduced negative behaviors whereas there were no training-related changes in the other groups. In terms of affective states, the rhythm and robot groups showed greater negative affect, whereas the comparison group demonstrated greater interested affect across all sessions. With training, the rhythm group showed a reduction in negative affect and an increase in interested affect whereas the robot group showed a reduction in positive affect. Overall, it appears that rhythm-based interventions are socially engaging treatment tools to target core impairments in autism.

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Keywords

Music; rhythm; robots; autism; repetitive behaviors; affective states; multisystem interventions

1. Introduction

The current diagnosis of Autism Spectrum Disorder (ASD) is based on social communication impairments and the presence of restricted and repetitive behaviors and interests (American Psychiatric Association, 2013). In terms of repetitive and maladaptive behaviors (RMBs), children with ASD demonstrate sensory behaviors such as odd peering at objects and repetitive spinning of toys, stereotyped behaviors involving repetitive movements of their bodies such as hand flapping and finger flicking, as well as negative behaviors such as self-injurious behaviors, aggression, defiance, and tantrums (Dominick, Davis, Lainhart, Tager-Flusberg, & Folstein, 2007; Hartley, Sikora, & McCoy, 2008; Leekam, Prior, & Uljarevic, 2011; Reese, Richman, Belmont, & Morse, 2005; Richler, Bishop, Kleinke, & Lord, 2007; Turner, 1999). In addition, children demonstrate significant affective impairments including poor affect expression using facial expressions, eye contact, and gestures, as well as impaired regulation of affective states, for example, flat facial expressions, low levels of positive affect/smiles, and greater negative affect (Maskey, Warnell, Parr, Le Couteur, & McConachie, 2013; Mazefsky, Pelphrey, & Dahl, 2012; Stagg, Slavny, Hand, Cardoso, & Smith, 2013). High levels of RMBs and poor affect regulation could reduce children's opportunities to learn through social interactions and exploration of their environment, and may therefore negatively impact their overall development (Cunningham & Schreibman, 2008; Koegel & Covert, 1972; Richler, Huerta, Bishop, & Lord, 2010; Stagg et al., 2013). In fact the presence and severity of RMBs is negatively associated with the acquisition of social, language, cognitive, play, and daily living skills in children with ASD and is also socially stigmatizing for the child (Bishop, Richler, & Lord, 2006; Cunningham & Schreibman, 2008; Gabriels, Cuccaro, Hill, Ivers, & Goldson, 2005; Hartley et al., 2008; Morgan, Wetherby, & Barber, 2008). In addition to costs for the child with ASD, poor behavior and affect regulation could lead to significant caregiver stress and impaired family dynamics (Gabriels et al., 2005). Hence, considerable research has been devoted towards developing interventions for reducing RMBs and improving affective states in children with autism (Gabriels et al., 2005; Turner, 1999). In this study, we examined the effects of two novel embodied interventions, rhythm and robotic therapies, on RMBs and affective states of children with ASD.

Behavioral interventions used to decrease RMBs and facilitate positive affect in children with ASD are primarily of two types – (1) interventions that directly reduce RMBs and negative affective states by modifying events that occur prior to (antecedents) or as a result of (consequences) the maladaptive behavior (Boyd, McDonough, & Bodfish, 2012; Kern, Choutka, & Sokol, 2002; Lovaas, 1987; Rapp & Vollmer, 2005) and (2) interventions that promote children's social communication and behavioral skills and indirectly lead to a collateral reduction in RMBs and negative affect (Bauminger, 2002; Lee & Odom, 1996; Lee, Odom, & Loftin, 2007; Loftin, Odom, & Lantz, 2008; Oke & Schreibman, 1990). Interventions may use antecedent-modifying strategies such as simplifying steps of the target task, using visual picture schedules to facilitate transitions, keeping the environment structured and consistent, and allowing children to engage in preferred activities prior to demanding tasks, as well as consequence-modifying strategies such as ignoring problem behaviors, differential reinforcement, and physical blocking to reduce the occurrence of RMBs (Boyd et al., 2012; Kern et al., 2002; Rapp & Vollmer, 2005). In fact a systematic review of 26 studies using ABA-based interventions within school settings suggested that these interventions led to successful reductions in challenging behaviors in children with ASD (Machalicek, O'Reilly, Beretvas, Sigafoos, & Lancioni, 2007). In contrast to these approaches, other behavioral interventions such as the Early Start Denver Model (Rogers & Dawson, 2010), Pivotal Response Treatment (Vernon, Koegel, Dauterman, & Stolen, 2012), cognitive-behavioral interventions (Bauminger, 2002), and parent- /peer-mediated therapies (Green et al., 2010; Lee & Odom, 1996; Lee, Odom, & Loftin, 2007) expand the social and behavioral repertoire of children and thereby lead to an increase in positive affect with a collateral reduction in maladaptive behaviors. Typically, current autism interventions are intensive in nature and are delivered for 30–40 hours per week (Landa, 2007). However, these therapies do not necessarily capitalize on the interests and predilections of children with ASD. Therefore, there is a dire need to diversify autism interventions to include engaging therapies that tap into children's inherent strengths.

In recent times, there has been growing research investigating the efficacy of alternative multisystem therapies for children with ASD. Multisystem interventions such as rhythm and robotic therapies harness children's strengths including their music and technology-based interests to create enjoyable, child-preferred contexts that can enhance social communication, motor, and behavioral skills in ASD (Diehl, Schmitt, Villano, & Crowell, 2011; Srinivasan & Bhat, 2013). For example, music-based experiences provide a non-intimidating context for children to explore their environment and use music as a medium to express their creative potential (Srinivasan & Bhat, 2013; Wigram & Gold, 2006). Since children with ASD enjoy music and have heightened musical perception abilities (Bonnel, Mottron, Peretz, Trudel, & Gallun, 2003; Heaton, 2003), socially-embedded rhythmic contexts that promote eye contact, turn taking, singing, imitation, music making, and interpersonal synchrony could be used to promote social communication, perceptuo-motor, behavioral, and affective skills in children with ASD (Boso, Emanuele, Minazzi, Abbamonte, & Politi, 2007; Finnigan & Starr, 2010; Gold, Wigram, & Elefant, 2006; Kern & Aldridge, 2006; Kim, Wigram, & Gold, 2009; Lim & Draper, 2011; Overy & Molnar-Szakacs, 2009; Srinivasan & Bhat, 2013; Stephens, 2008; Wimpory, Chadwick, & Nash, 1995). In fact, a Cochrane meta-analysis suggested that music-based training led to significant improvements in verbal and gestural communication skills compared to placebo therapy in children with ASD (Gold et al., 2006). Along the same lines, robots have been used as therapeutic tools to facilitate social communication and motor skills in children with ASD (Diehl et al., 2011). Robot-child interactions allow children to learn in highly motivating, simple, and predictable environments in contrast to the conventional, complex, and variable learning environments characteristic of adult-child interactions (Wainer & Ingersoll, 2011). Hence, robots have been used as a focus of shared attention and as a mediator to promote interactions of children with their social partners (Costa, Santos, Soares, Ferreira, & Moreira, 2010; Dautenhahn & Werry, 2004; Feil-Seifer & Mataric, 2009; Kozima, Nakagawa, & Yasuda, 2007; Robins, Dautenhahn, & Dickerson, 2009; Robins, Dautenhahn, Te Boekhorst, & Billard, 2005; Scassellati, Admoni, & Mataric, 2012). Our own previous work suggests that robot-adult-child interactions can be used to promote motor skills, including imitation, praxis, and bilateral coordination, as well as social communication skills, including social attention and verbalization, in a small sample of children with ASD (Kaur, Gifford, Marsh, & Bhat, 2013; Srinivasan, Gifford, Bubela, & Bhat, 2013; Srinivasan & Bhat, 2013). In spite of promising evidence on the positive effects of rhythm and robotic therapies in autism, the majority of studies conducted to date are limited by small sample sizes, lack of comparison groups, limited training duration, and lack of standardized assessments (Diehl et al., 2011; Gold et al., 2006; Srinivasan & Bhat, 2013). Therefore, we addressed these limitations by systematically comparing the effects of 8-week rhythm and robotic therapies with those of a standard-of-care intervention on the behavioral, affective, social communication, and motor skills of 36 school-age children with ASD using a randomized controlled trial (RCT) design.

In our pilot RCT, 36 children with ASD between 5 and 12 years were randomly assigned to one of the three groups – rhythm, robot, or comparison, with 12 subjects in each group. The comparison group received tabletop sedentary activities similar to activities that children with ASD typically receive within school settings with a focus on fine motor, academic, and social communication skills, for example, reading, building, and art-crafts. In this paper, we restrict our discussion to the effects of the three interventions on RMBs and affective states of children. Specifically, we examined the frequencies of sensory, negative, and stereotyped behaviors and the duration of positive, negative, and interested affect during an early, mid, and late training session in all groups. Our research aims were: (1) to assess *group differences* in RMBs and affective states across sessions and (2) to examine *training-related changes* in RMBs and affective states across sessions within each group. We hypothesized that the types of RMBs and affective states in children would vary based on the nature of the training context and the activities practiced. For example, given the novelty of the training activities and the opportunities for whole-body movements, the rhythm and robotic groups would initially demonstrate greater frequencies of negative and stereotyped behaviors as well as greater duration of negative affect; in contrast, the comparison group that had easy access to objects/supplies and practiced activities that were highly familiar would engage in greater repetitive sensory behaviors with objects and demonstrate high levels of interested affect. We also expected that children in all three groups would demonstrate a training-related reduction in frequencies of RMBs and an increase in the duration of positive affect.

2. Method

2. 1. Participants

Thirty-six children with ASD (32 males and 4 females; 20 Caucasian, 6 African American, 4 Asian, 3 Hispanic, 2 mixed Caucasian and Hispanic, 1 mixed Caucasian and African American) between 5 and 12 years of age were recruited (see Table 1 for demographic details). Socioeconomic status of families was assessed using the Hollingshead scale (Hollingshead, 1975). Children were recruited through fliers posted online and onsite in local schools, services, and self/parent advocacy groups. The Social Communication

Questionnaire (SCQ) (Rutter, Bailey, & Lord, 2003) was used as a screener prior to enrollment in the study. Eligibility of children was confirmed using the Autism Diagnostic Observation Schedule −2, a gold standard diagnostic assessment for ASD (Lord et al., 2012) and clinician judgment during a clinical psychology evaluation. Four children with significant behavioral impairments or severe receptive language impairments that limited their comprehension of simple instructions and participation in the training activities were excluded. Children were enrolled following written parental consent approved by the Institutional Review Board at the University of Connecticut.

Children were matched on age bands (4–5, 6–7, 8–9, and 10–12 years) and level of functioning as assessed on the Vineland Adaptive Behavior Scale, 2nd edition (VABS) (Sparrow, Cicchetti, & Balla, 2005) and then randomly assigned to one of the three groups: rhythm, robot, or comparison (see Table 1). Overall, 82% of our sample had delays (> 1SD below the mean) on the Adaptive Behavior Composite of the VABS; specifically, 70% children had communication delays, 80% had delays in daily living skills, and 82% had delays on the socialization domain (see Table 1). We also assessed the severity and variety of children's repetitive behaviors using the parent questionnaire, Repetitive Behavior Scale – Revised (RBS-R) (Lam & Aman, 2007) (see Table1).

2.2. Procedure

The study was conducted over 10 weeks, with the pretest and posttest conducted during the first and last weeks of the study. The training was provided over the intermediate eight weeks, with four sessions (two expert and two parent sessions) provided each week, for a total of 32 sessions. Each expert training session was conducted within a triadic context involving the trainer, the child, and an adult model and lasted for approximately 45 minutes (see Figure 1A, 1B and 1C). The adult model was the child's confederate and practiced all activities with the child. In the robot group, the robot was the primary trainer and the adult trainer mainly controlled the robot (see Figure 1B). All expert trainers were physical therapists or physical therapy/kinesiology graduate students with significant pediatric training. Note, that all trainers and models were unfamiliar to children at the beginning of the study. All trainers and adult models involved in the study received significant training from the last author and ABA experts prior to participation. All three groups engaged in joint action-based gross motor and/or fine motor activities that promoted social skills such as eye contact, turn taking, greeting, and imitation as well as communication skills such as use of gestures, commenting, and responding. In terms of motor skills, the rhythm and robot groups promoted balance, coordination, interpersonal synchrony, imitation, and manual dexterity during movement-based games. In contrast, the sedentary context in the comparison group promoted fine motor skills involving coloring, cutting, drawing, gluing, as well as symmetrical and asymmetrical grips and pinches. Children in all groups were provided with multiple opportunities for spontaneous play and free exploration. All expert sessions were videotaped for behavioral coding of several variables. We also encouraged parents to provide two additional sessions involving similar activities each week to promote practice. Parents were provided with detailed instruction manuals, appropriate supplies, and in-person training each week. Out of the total 32 sessions (16 expert and 16 parent), all families completed the majority of the home sessions (% of sessions completed: Rhythm: M

(SD) = 73.18(19.74), Robot: M (SD) = 76.82(16.72), Comparison: M (SD) = 80.21(15.27), *ps* >0.05). Next, we discuss training activities in each group. The rhythm group engaged in singing, synchronous movement, and imitation games (see Figure 1A). The training involved the following conditions – an introductory greeting song, action song involving finger play, beat keeping activity involving whole body movements to the rhythm, improvisational music making using musical instruments, moving game involving whole body interpersonal synchrony games, calming song for relaxation, and a farewell song to bid goodbye. In the robot group, a 23" humanoid robot, Nao (Aldebaran Robotics) and a mobile robot, Rovio™ (WowWee®) delivered the training involving imitation and interpersonal synchrony-based games, while the trainer controlled the robots via a custom software and laptop system (see Figure 1B). The training involved the following conditions – a greeting condition, warm up game involving body stretches, action game involving rhythmic upper and lower body interpersonal synchrony games, drumming game involving practice of simple and complex drumming patterns, walking game involving tracing letters and shapes on the floor while following the Rovio™ robot, and lastly farewell condition. In the rhythm and robot groups, sessions were based on action themes such as start and stop, slow and fast, moving on a count, moving on a steady beat, and turn taking.

The comparison group engaged in sedentary, tabletop activities that focused on promoting social communication, academic, and fine motor skills (see Figure 1C). Training conditions included an introductory greeting, reading a book appropriate to the child's developmental level, building involving making creations using Play-Doh®, Duplo® blocks, Zoob (Infinitoy®), or building blocks, art and crafts involving drawing, coloring, cutting, and gluing to make theme-based creations, and a farewell condition. Session themes included basic shapes, solar system, people and the human body, healthy foods, and weather/seasons.

In all groups, we used training principles from contemporary autism interventions such as ABA (Lovaas, 1987), Picture Exchange Communication System (PECS) (Bondy & Frost, 2003), and Treatment and Education of Autistic and related Communication-Handicapped Children (TEACCH) (Mesibov, Shea, & Schopler, 2004) to reduce the frequency of RMBs and improve affective states during training sessions. We included both antecedent strategies such as using a consistent training environment/trainers/supplies, providing clear and simple instructions prior to the task, using picture schedules, and breaking down each activity into simple steps as well as consequence modifying strategies such as differential reinforcement, ignoring RMBs, giving intermittent breaks, and providing child-preferred activities following completion of the session.

To assess treatment fidelity, we asked an unbiased coder to randomly choose and code an early (sessions 1–5), mid (sessions 6–11), and late (sessions 12–16) expert training session for each child. Specifically, the coder assessed the quality of trainer and model behaviors on a Likert scale using a comprehensive checklist. The coder evaluated for (1) accurate completion of critical components of training activities (maximum score = 74 points), (2) trainer and model behaviors including instructions, prompts, and trainer/model affect (scored on a scale of 1 to 5 with 1 indicating poor quality and 5 indicating highest quality), and (3) child's compliance (scored on a scale of 1 to 5 with 1 indicating poor interest and 5 indicating maximum interest). Overall, across all groups and sessions, training conditions were completed accurately (Rhythm: 92.16%, Robot: 90.73%, Comparison: 91.51%), trainers and models demonstrated greater than optimal compliance with the training protocol (Rhythm: 4.68, Robot: 4.36, Comparison: 4.65), and children showed moderate to high levels of compliance with training (Rhythm: 3.27, Robot: 2.67, Comparison: 3.95).

2. 3. Behavioral Coding

2.3.1. Repetitive and Maladaptive behaviors—We coded for the frequencies in standard time of sensory, negative, and stereotyped behaviors during an early, mid, and late training session in all groups. Bouts of movements that involved > 2 RMBs were scored. Sensory behaviors included repetitive movements with objects involving the visual, auditory, tactile/proprioceptive, olfactory, or vestibular modalities, for example, atypical peering, spinning, smelling, twiddling, slapping, pressing, and throwing objects. Negative behaviors included self-injurious behaviors such as biting, poking, pinching, scratching, picking, and hitting oneself with objects or against surfaces, episodes of non-compliance such as yelling, running away, tantrums, and crying, inappropriate social conduct/social distance as well as use of repetitive language. Stereotyped behaviors involved repetitive movements of the body including rocking, swaying, head rolling/nodding/turning, arm flapping/waving/shaking, finger flicking, and leg shaking/bouncing. Two coders coded 20% of the dataset to establish intra- and inter-rater reliability of over 90%. Following the process of reliability, one of the two coders coded the remaining dataset.

2.3.2. Affective states—We coded for the percent duration of time that children demonstrated positive, negative, and interested affect during an early, mid, and late training session. Positive affect included time spent smiling, negative affect included time spent in off-task behaviors such as looking away, pouting, frowning, and clear distress, and interested affect included time spent on-task, in compliance with the training while not smiling or demonstrating negative affect. Two coders established intra- and inter-rater reliability of > 90% based on 20% of the dataset. Following the process of reliability, one of the two coders coded the remaining dataset.

2. 4. Statistical Analysis

Prior to inferential statistics, data were checked for assumptions of parametric statistics including normal distribution and homogeneity of variances. Since the RMB and affective states data were not normally distributed and had outliers, a square root transformation was applied to these data and transformed data were used within the repeated measures ANOVAs. The first ANOVA included RMB type (sensory, negative, stereotyped) and session (early, mid, late) as the within-subjects factors, and group as the between-subjects factor. The second ANOVA had affective states (positive, negative, and interested) and session (early, mid, late) as the within-subjects factors, and group as the between-subjects factor. In case of violations of the Mauchly's test of sphericity, Greenhouse Geisser corrections were applied. If there was a significant main effect and an interaction, post-hoc *t*-tests were conducted to evaluate the significant interactions only. In case of significant 2-way and 3-way interactions involving the same factors, the 3-way interactions were analyzed further using post-hoc *t*-tests. Effect sizes are reported using partial eta-squared

(n_p) and standardized mean difference (SMD) values (using Hedge's g) (Hedges, 1981). Statistical significance was set at $p < 0.05$.

3. Results

3.1. Repetitive and Maladaptive behaviors

The repeated measures ANOVA suggested a significant main effect of RMB type (F *(2*, 66) = 5.34, p = 0.007, η^2_p = 0.14), an RMB type × group interaction (F *(4*, 66) = 7.53, p < 0.001, η^2_p = 0.31), and a session × RMB type × group interaction (F (8,132) = *2.01*, p = 0.05, η^2_p = 0.11). We report post-hoc testing of the session × RMB type × group as between-group differences and within-group, training-related changes.

3. 1.1. Between-group differences—In terms of sensory behaviors, the comparison group demonstrated significantly greater frequencies of behaviors compared to the rhythm group in the early and mid sessions (Rhythm - *Early:* M(SD) = 12.33(10.51), *Mid:* M(SD) = 13.21(10.15); Comparison - *Early:* M(SD) = *37.60(27.63)*, *Mid:* M(SD) = 31.28(28.47), p < 0.05) (see Figure 2A). In the late session, the comparison group demonstrated greater sensory behaviors compared to both rhythm and robot groups (*Rhythm:* M(SD) = 10.79(12.62), *Robot:* M(SD) = 10.53(8.56), *Comparison:* M(SD) = 29.72(19.31), *ps* ≤ 0.01) (see Figure 2A). In terms of negative behaviors, the rhythm and robot groups exhibited greater behaviors compared to the comparison group in the early session only (*Rhythm:* M(SD) = 60.86(46.81), *Robot:* M(SD) = 35.39(29.81), *Comparison*: M(SD) = 13.39(16.07), *ps* < 0.05) (see Figure 2B). No significant group differences were observed for stereotyped behaviors (see Table 2).

3. 1. 2. Within-group training-related changes—In terms of training-related changes, the rhythm group demonstrated significantly lower frequencies of negative behaviors in the late (SMD = 0.66) and mid (SMD = 0.50) sessions compared to the early session (*Early*: M(SD) = 60.86(46.81), *Mid*: M(SD) = 35.76(17.72), *Late*: M(SD) = 27.76(24.79), *ps* ≤ 0.05) (see Figure 2B). In terms of individual data, 9 out of 12 children followed the group trends. There were no training-related changes in RMBs in the robot and comparison groups.

3. 2. Affective states

The repeated measures ANOVA suggested significant main effects of affect type (F (1.69, 298.45) = 910.69, p < 0.001, η_p^2= 0.84) and group (F (2, 177) = 24.36, p < 0.001, η_p^2= 0.22) as well as interaction effects of session × group (F (4, 354) = 4.30, p = 0.002, η_p^2= 0.05), affect type × group (F (4, 354) = 12.19, p < 0.001, η_p^2= 0.12) and session × affect type × group (F (8, 708) = 2.35, p = 0.02, η_p^2= 0.03). We report post-hoc testing of the session × affect type × group as between-group differences and within-group, training-related changes.

3. 2.1. Between-group differences—The rhythm group engaged in greater positive affect compared to the robot group in the mid and late sessions (Rhythm - *Mid*: M(SD) = 8.85(14.75), *Late*: M(SD) = 5.77(8.71); Robot - *Mid*: M(SD) = 2.31(6.05), *Late*: M(SD) = 1.68(3.94), *ps* < 0.002) (see Figure 3A). The rhythm group also had significantly greater positive affect compared to the comparison group in the mid session (*Rhythm:* M(SD) = 8.85(14.75); *Comparison: Mid*: M(SD) = 2.92(7.02), $p = 0.006$) (see Figure 3A). The amount of negative affect was greater in the robot and rhythm groups compared to the comparison group in all three sessions (Rhythm -*Early*: M(SD) = 22.57(20.66), *Mid*: M(SD) = 18.86(21.85), *Late*: M(SD) = 15.43(19.27); Robot - *Early*: M(SD) = 17.87(20.32), *Mid*: M (SD) = 18.86(21.85), *Late*: M(SD) = 22.07(22.09); Comparison - *Early*: M(SD) = 8.81(18.24), *Mid*: M(SD) = 9.58(16.48), *Late*: M(SD) = 6.89(13.72), $ps < 0.05$) (see Figure 3B). The duration of interested affect was greater in the comparison group compared to the rhythm and robot groups in the early, mid, and late sessions (Rhythm - *Early*: M(SD) = 68.41(22.35), *Mid*: M(SD) = 72.56(21.84), *Late*: M(SD) = 78.80(19.53); Robot - *Early*: M(SD) = 76.53(20.18), *Mid*: M(SD) = 78.83(22.64), *Late*: M(SD) = 76.25(23.04); Comparison - *Early*: M(SD) = 86.77(21.74), *Mid*: M(SD) = 87.49(17.67), *Late*: M(SD) = 89.55(15.72), $ps < 0.05$) (see Table 3).

3. 2. 2. Within-group training-related changes—The rhythm group demonstrated a decrease in negative affect (SMD = −0.32) and a concurrent increase in interested affect (SMD = 0.43) from the early to the late session (Negative - *Early*: M(SD) = 22.57(20.66), *Late*: M(SD) = 15.43(19.27), Interested - *Early*: M(SD) = 68.41(22.35), *Late*: M(SD) = 78.80(19.53), $ps \leq 0.002$) (see Figure 3B and Table 3). Individual data suggest that 9 out of 12 children followed the group trends. The robot group demonstrated a reduction in positive affect from the early to the mid (SMD = −0.26) and from the early to the late session (SMD = −0.31) (*Early*: M(SD) = 5.60(11.85), *Mid*: M(SD) = 2.31(6.05), *Late*: M(SD) = 1.68(3.94), $ps < 0.02$) (see Figure 3A). In terms of individual data, 6–8 out of 12 children followed the group trends. The comparison group did not demonstrate any training-related changes in affective states.

4. Discussion

4. 1. Context-related group differences in RMBs

At baseline, the three groups did not differ in the frequency and severity of RMBs measured on the RBS-R as well as their behavioral and affective regulation skills measured on the VABS. Therefore, we believe that group differences in types of RMBs and affective states during the early session are reflective of context-specific differences evoked by the nature of the training activities. Accordingly, the rhythm and robot groups demonstrated greater levels of negative behaviors and negative affect than the comparison group possibly due to the novelty and unconstrained nature of the contexts, as well as the challenging nature of the training activities. The movement groups engaged in multilimb activities involving interpersonal synchrony, imitation, balance, and coordination that were relatively novel for children, as they are typically not practiced within therapy settings. Children with autism typically prefer familiar, highly structured activities that allow them to anticipate task demands and perform activities with little anxiety (Schopler, 1986; Schopler, Mesibov, & Baker, 1982). In addition, given their emphasis on whole-body movement, the rhythm and robotic contexts were relatively unconstrained, allowed children to move freely, and therefore provided children with greater opportunities to demonstrate negative behaviors such as running away. Lastly, the training activities were motorically challenging for children with ASD. There is growing evidence that over 50% of children with ASD demonstrate perceptuo-motor impairments including poor balance and coordination, clumsy gait patterns, as well as impaired imitation and synchrony skills (Bhat, Landa, & Galloway, 2011; Dewey, Cantell, & Crawford, 2007; Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Green et al., 2009; Hallett et al., 1993; Manjiviona & Prior, 1995; Mostofsky et al., 2006). Therefore, in lines with other research, children may have engaged in RMBs to escape from the demanding unfamiliar activities or to regulate their stress/arousal levels (Cunningham & Schreibman, 2008; Joosten, Bundy, & Einfeld, 2009; Leekam et al., 2011; Lewis & Bodfish, 1998; Conroy, Asmus, Sellers, & Ladwig, 2005; Durand & Carr, 1987). In contrast to the movement groups, the comparison group engaged in highly familiar activities similar to those practiced at school (Landa, 2007), within a stationary context. This may have significantly limited children's opportunities to demonstrate off-task behaviors such as running away. Evidence from contemporary autism interventions such as TEACHH suggest that constrained, clearly demarcated, predictable, and distraction-free environments allow children to focus effectively on the task at hand and reduce the frequency of off-task maladaptive behaviors (Panerai, Ferrante, & Caputo, 1998; Schopler, Mesibov, & Hearsey, 1995). Therefore, the very nature of the context and training activities may have promoted highest levels of interested affect and lowest levels of negative behaviors in the comparison group.

The comparison group demonstrated greater sensory behaviors compared to the movement groups. Possible reasons include the nature of the training activities, children's preference for non-social play, their difficulties in disengaging attention, and the limited nature of object-play in autism. The comparison group aimed to promote triadic social interactions within a stationary setting as children engaged in goal-oriented group activities using supplies such as Play-Doh®, Duplo® blocks, Zoob (Infinitoy®), crayons, and glue. The very proximity of the supplies/objects provided children with multiple opportunities to engage in object-directed play. Other research also suggests that children who later developed ASD engaged in greater episodes of non-social exploration with objects instead of interactions with social partners during infancy and early childhood (Maestro et al., 2005; Maestro et al., 2006; Swettenham et al., 1998; Williams, Reddy, & Costall, 2001). In addition, difficulty disengaging attention (Landry & Bryson, 2004) and shifting attention between objects and people (Lewy & Dawson, 1992; McArthur & Adamson, 1996; Swettenham et al., 1998) could also contribute to children engaging in repetitive actions with select objects (Turner, 1999). It has been proposed that children with ASD have difficulties in generating new types of behaviors (Turner, 1999) and this lack of creativity may lead to inflexible, less diverse, and primitive play compared to age-appropriate and functional play skills (Hobson, Lee, & Hobson, 2009; Jarrold, Boucher, & Smith, 1996; Lewis & Boucher, 1995; Libby, Powell, Messer, & Jordan, 1998; Williams, 2003). Along these lines, the comparison group engaged in primitive and repetitive exploration of objects, including peering, rubbing, tapping, and sniffing. In contrast, the movement groups relied less on supplies/objects and instead engaged in whole-body movement games that may have contributed to lower levels of sensory behaviors.

4. 2. Training-related changes in RMBs within groups

The rhythm group reduced the frequencies of negative behaviors across training weeks. In terms of affective changes, children demonstrated higher levels of positive affect compared to the other two groups in the mid and late sessions. Moreover, children reduced levels of negative affect with a concurrent increase in interested affect from the early to the late session. Our findings fit with other studies that found a reduction in problem behaviors as well as an increase in enjoyment, positive affect, and compliance following active and passive music therapies involving listening, singing, and instrument playing (Boso et al., 2007; Brownell, 2002; Kim et al., 2009; Lundqvist, Andersson, & Viding, 2009; Orr, Myles, & Carlson, 1998; Pasiali, 2004; Rapp, 2007). The non-intimidating yet enjoyable nature of musical experiences could induce positive affective states, improve compliance, and reduce negative and problem behaviors in children with ASD (Srinivasan & Bhat, 2013). Moreover, we propose that socially embedded musical experiences can improve social communication and motor skills in children with ASD which in turn may lead to increased compliance/ interest with a collateral reduction in negative behaviors and negative affect across training weeks (Leekam, Uljarevic, & Prior, 2011; Loftin et al., 2008; Srinivasan & Bhat, 2013). Other studies have also reported to improvements in social engagement skills including eye contact, compliance, and reciprocal interactions with caregivers and peers following music training in children with ASD (Kern & Aldridge, 2006; Kim, Wigram, & Gold, 2008; Kim et al., 2009; Wimpory et al., 1995). Our own observations suggest that across sessions, the rhythm group engaged in more task-appropriate social behaviors including turn taking, synchronous singing and joint action, social monitoring, smiling, and verbal interactions with adults. Moreover, we observed that the repeated practice of gross and fine motor activities also led to improved motor imitation skills in this group. Overall, rhythmic movement-based activities might be initially challenging for children but over time afford positive affective states, compliance, and functional social communication and motor skills, as well as lead to a reduction in maladaptive behaviors. Our findings call for the inclusion of creative movement-based interventions such as rhythm, dance, yoga, and active play therapies into the standard-of-care treatment of autism.

In contrast to the rhythm group, the robot group did not demonstrate any improvements in RMBs. Similarly children reduced levels of positive affect from the early to mid and early to late session. Moreover, individual data suggest that 8 out of 12 children increased negative behaviors and 9 out of 12 children showed an increase in negative affect with training. These findings could be due to the technical limitations of the robot that made the context less compelling than the other two training contexts. Although we used the state-of-the-art humanoid Nao robot with 25 degrees of freedom, the robot’s movements were much slower, noisier, and less diverse than the natural movement repertoire of children, the robot’s pre-programmed verbiage was unclear and slightly delayed, and there were several technical issues such as overheating and equipment failure. Once the initial excitement and novelty associated with the robot wore off, even low-functioning children with ASD were bored and showed an increase in negative behaviors including tantrums and non-compliance with the training. Our findings fit with two other training studies that also used the Nao robot and found equivocal results (Huskens, Verschuur, Gillesen, Didden, & Barakova, 2013; Tapus et al., 2012). For example, during robot-adult-child interactions within an imitation context, improvements in motor initiation, eye contact, and positive affect were seen in only 2 of the 4 children (Tapus et al., 2012). Similarly, an ABA-based intervention delivered by the robot to promote self-initiated questions was only as effective as training provided by a human instructor (Huskens et al., 2013). However, our findings are in contrast to a majority of the previous literature on the use of robots in children with ASD. For example, a comparison of stereotyped behaviors of children during a 15-minute human versus robotic interaction suggested that robotic interactions led to lower stereotyped behaviors compared to human interactions (Shamsuddin et al., 2012b). Along the same lines, several other studies have documented positive effects of robotic interactions on eye contact, turn-taking, joint attention, and verbal communication in children with ASD (Bekele, Crittendon, Swanson, Sarkar, & Warren, 2014; Cabibihan, Javed, Ang Jr, & Aljunied, 2013; Diehl et al., 2011; Shamsuddin et al., 2012a; Tapus et al., 2012; Warren et al., 2013). However, most of these studies provided short duration of training lasting between 1 and 10 sessions. Only three studies examined the effects of repeated interactions over several months with humanoid robots such as Robota and KASPAR (Dautenhahn et al., 2009; Robins, Dickerson, Stribling, & Dautenhahn, 2004) or creature-like robots such as Keepon (Kozima et al., 2007), and reported qualitative improvements in turn-taking, shared attention, and imitation skills, while still sustaining engagement of children. However, in these studies, children were either allowed to freely approach the robot based on their will or the duration of interactions was very brief (on an average 3 minutes) and was terminated once children demonstrated boredom (Kozima et al., 2007; Robins et al., 2004). In contrast, children in our study engaged in 45-minute sessions with robots for an intense 32-session protocol over 8 weeks. Our study suggests that the current robotic technology is unable to sustain children's engagement over prolonged durations. Future studies should develop contingent, semiautonomous robots and diverse training activities that can sustain children's engagement over prolonged training durations.

The comparison group did not show any improvements in RMBs or affective states with training. As discussed previously, the comparison group had low levels of negative behaviors and highest levels of compliance/interest compared to the movement groups probably due to the familiar and predictable nature of the training activities. However, children also did not demonstrate any training-related reduction in frequencies of sensory behaviors. The nature of the training context, the easy access to objects/supplies, and children's preference for non-social exploration may have contributed to persistent sensory behaviors in this group across sessions. We believe that sedentary contexts employed in standard-of-care interventions are ideal for educational purposes since children are relatively constrained and this ensures greater on-task behaviors and compliance. But academic and fine motor activities with objects/props afford greater primitive and repetitive object-directed non-social exploration. Attention data from our study also suggest that children in the comparison group spent maximum time looking at objects, whereas children in the movement groups looked most at their social partners. Overall, our findings underscore the importance of dyadic, object-free contexts to promote social engagement in children with ASD.

4. 4. Conclusions

Although promising, our findings are limited by a small sample size, variability in the level of functioning of children, relatively short training duration, lack of follow-up sessions, variability in the compliance levels of parents with training, and lack of blinding of coders. Our study suggests that although initially novel and challenging for children, rhythm-based interventions can be used to promote behavioral skills and positive affect in children with ASD. Robotic contexts are currently somewhat limited in sustaining children's engagement across multiple sessions due to the technical limitations of the robot. Although stationary contexts afford maximum compliance and on-task behaviors, there is an urgent need for the inclusion of object-free, creative movement interventions involving rhythm, dance, yoga, and play therapies into the standard-of-care treatment of children with autism.

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Highlights

- Effects of rhythm and robotic interventions in autism were assessed
- Movement groups showed greater negative behaviors and negative affect initially
- Comparison group had greater sensory behaviors with objects and interested affect
- Rhythm group reduced negative behaviors and demonstrated greater positive affect
- Rhythm therapies are enjoyable and can address core impairments in autism

Figure 1.

A: Experimental set-up for a rhythm group training session

B: Experimental set-up for a robot group training session

C: Experimental set-up for a comparison group training session

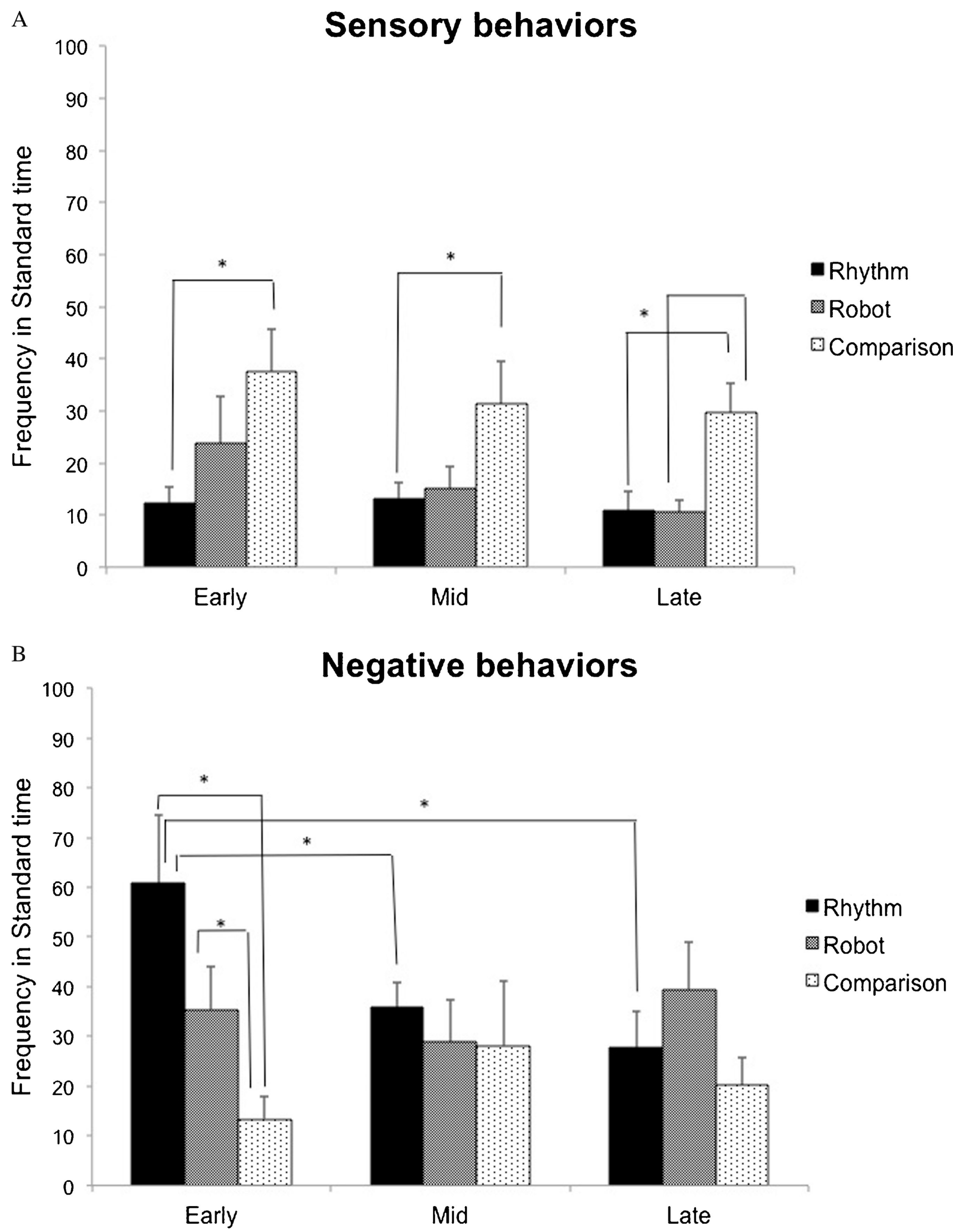

Figure 2.

A: Group differences in the frequencies of sensory behaviors

B: Group differences in the frequencies of negative behaviors

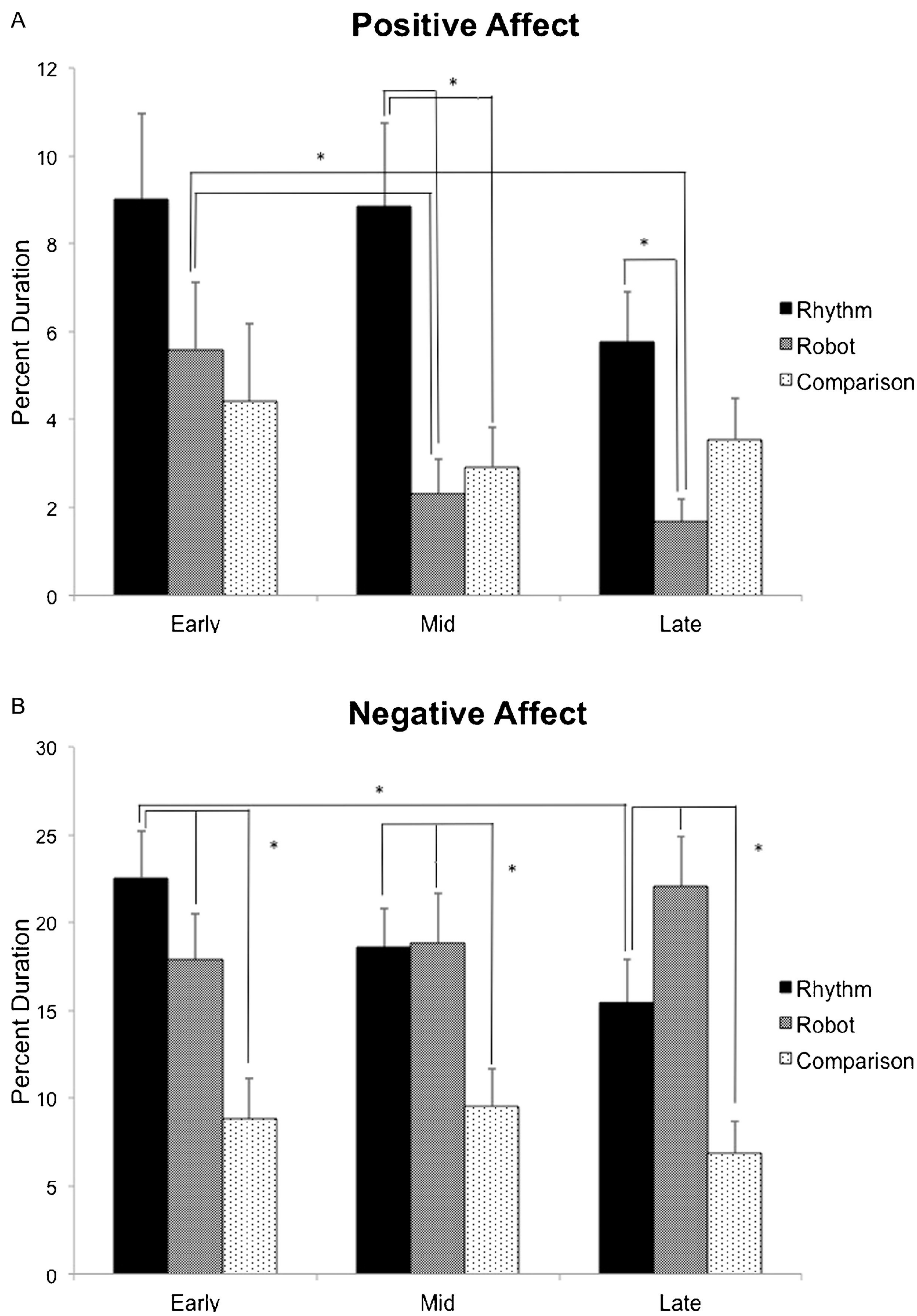

Figure 3.
A: Group differences in the percent duration of positive affect
B: Group differences in the percent duration of negative affect

Table 1

Demographic characteristics of children in the rhythm, robot, and comparison groups

Participant Characteristics	Rhythm Group M(SD)	Robot Group M(SD)	Comparison Group M(SD)	*p* value
Age	7.88(2.56)	7.52(2.22)	7.36(2.02)	0.65
Gender	10M, 2F	11M, 1F	11M, 1F	0.76
Socioeconomic status	47.33(10.86)	47.75(8.75)	52.46(10.37)	0.39
Adaptive behavior composite on the VABS	71.45(11.75)	67.91(15.01)	75.92(18.43)	0.46
Total scores on RBS-R	30.45(16.90)	28.17(20.23)	28.17(17.32)	0.75
Number of items endorsed on RBS-R	19.09(8.28)	17.17(10.48)	17.58(8.76)	0.62

Table 2

Frequencies in standard time of sensory, negative, and stereotyped behaviors in the rhythm, robot, and comparison groups

Group	Rhythm Group M(SD)			Robot Group M(SD)			Comparison Group M(SD)		
	Early	***Mid***	***Late***	***Early***	***Mid***	***Late***	***Early***	***Mid***	***Late***
Sensory	12.3 (10.5)	13.2 (10.1)	10.8 (12.6)	23.7 (30.9)	15.0 (14.7)	10.5 (8.6)	37.6 (27.6)	31.3 (28.5)	29.7 (19.3)
Negative	60.9 (46.8)	35.8 (17.7)	27.8 (24.8)	35.4 (29.8)	28.8 (29.4)	39.4 (33.3)	13.4 (16.1)	28.2 (45.1)	20.2 (19.5)
Stereotyped	16.0 (19.6)	20.5 (30.6)	17.4 (20.9)	26.30 (23.7)	29.4 (30.9)	19.3 (20.2)	10.1 (12.3)	12.4 (14.9)	12.2 (13.3)

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Table 3

Percent duration of positive, negative, and interested affective states in the rhythm, robot, and comparison groups

Group	**Rhythm Group M(SD)**			**Robot Group M(SD)**			**Comparison Group M(SD)**		
	Early	***Mid***	***Late***	***Early***	***Mid***	***Late***	***Early***	***Mid***	***Late***
Positive	9.0 (15.0)	8.9 (14.7)	5.8 (8.7)	5.6 (11.8)	2.3 (6.1)	1.7 (3.9)	4.4 (13.8)	2.9 (7.0)	3.6 (7.1)
Negative	22.6 (20.7)	18.6 (17.1)	15.4 (19.3)	17.9 (20.3)	18.9 (21.9)	22.1 (22.1)	8.8 (18.2)	9.6 (16.5)	6.9 (13.7)
Interested	68.4 (22.4)	72.6 (21.8)	78.8 (19.5)	76.5 (20.2)	78.8 (22.6)	76.3 (23.0)	86.8 (21.7)	87.5 (17.7)	89.6 (15.7)