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Dancing out for a voice; a narrative review of the literature exploring autism, physical activity, and dance☆

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ABSTRACT

Autism Spectrum Disorder is characterised by profound challenges with social communication and social interaction. Currently, there are few therapeutic interventions that successfully target some of the functionally impairing traits associated with autism. Furthermore, many of these interventions comprise a variety of limitations; including, limited accessibility, extensive durations, or the requirement of a trained professional to deliver the intervention. New research suggests that instead of targeting all traits associated with Autism Spectrum Disorder with a single solution, scientific research should focus on providing therapeutic tools that alleviate functionally impairing facets specific to the individual. Owing to the nature of physical activity, sports, and dance (coordinated movement) these activities could provide opportunities to enhance communication skills and social development in autistic children. Therefore, this paper gives a narrative overview of the literature surrounding communication and coordinated movement; outlining what is meant by communication challenges, exploring the benefits of coordinated movement for traits associated with Autism Spectrum Disorder, and delineating how coordinated movement elicits positive outcomes for autistic children.

1. Introduction

Autism or Autism Spectrum Disorders (ASDs) include a spectrum of neurodevelopmental conditions experienced by a large number of both children and adults across the world (National Autistic Society, 2019). At a symptomatic level, autism is most commonly described as persistent challenges to social communication and social interaction within multiple contexts and across restricted, repetitive patterns of behaviour, interests, or activities, which can result in clinically significant disadvantages in social, occupational, or other main areas of functioning (American Psychiatric Association; APA, 2013). Although the direct cause of autism is unknown, the available evidence suggests that an interaction between genes and the environment results in changes from typical brain development (Chaste and Leboyer, 2012; Tordjman et al., 2014). Due to the complexity of the disorder and its strong heterogeneity, new research proposes that instead of attempting to alleviate all facets associated with ASD with a single solution, scientific research should attempt to provide therapeutic tools that reduce traits, which impair present functioning (Lombardo et al., 2019). These symptom-specific interventions can then be used in combination with other practices aiming to minimise or reduce a variety of functionally impairing traits as defined by the individual; thus, leading to a better quality of life (QoL) for autistic individuals.

It should be recognised that some autistic individuals do not wish to be 'treated' or participate in interventions targeting facets associated with ASD as they see their diagnosis simply as a difference or neurodiversity and not something that requires intervention. However, due to the spectrum of autism, some autistic individuals or parents of autistic children may feel that they could benefit from additional support; whilst still celebrating their neurodiversity. Therefore, increasing the development of symptom-specific interventions will allow researchers and clinicians to target functionally impairing facets associated with ASD and enhance skills already upheld by each autistic individual they work with (Hart, 2014; Kapp et al., 2013; National Autistic Society, 2019).

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1.1. Communication is an autistic-prioritised outcome

The very earliest descriptions of ASD reported challenges to social interaction and poor communication skills (Kanner, 1943). At present, these difficulties and differences are now central to the diagnostic definition of autism (APA, 2013), with social-communication differences appearing to arise during early childhood and presenting in several different ways. For example, impairments in non-verbal communicative behaviours, challenges in social-emotional reciprocity, and difficulties in developing, maintaining, and understanding relationships. Such social-communication differences can lead to a poor QoL, due to reduced interaction in recreational activities, the feeling of isolation, and increased loneliness. Owing to the impact of communication difficulties in everyday life, promoting language development and communication has been outlined as one of the autistic community's top priorities for research (Autistica, 2016). Researchers and practitioners should be working with autistic communities to address autistic prioritised outcomes (Leadbitter et al., 2021). Therefore, developing new and innovative interventions that enhance autistic peoples' communication skills should currently be a top research priority; enabling neurodivergent individuals to successfully navigate the social world we all live in and ensure they can live as independently and as rewardingly as possible.

Although there have been advances in interventions and therapies that gently address the social-communication differences experienced by autistic individuals in a supportive and caring way, more work is needed. For example, interventions that target communication skills; such as, Social Skills Training, the Picture Exchanges Communication System (Bondy and Frost, 1994), or the Early Start Denver Model (Dawson et al., 2010), are often intensive and extensive, require a trained professional to deliver the intervention, or require travelling to various sites to participate in the intervention (Lee and Meadan, 2020). Thus, highlighting some of the limitations generated by the more traditional styles of therapy.

In contrast, it is believed that physical activity, movement, and dance; also referred to as coordinated movement, can be used as exciting vehicles to enhance social-communication skills in children diagnosed with ASD in a more naturalistic way, whilst also increasing QoL (Berlandy, 2019; Chan et al., 2020; Güeita-Rodríguez et al., 2021; Howells et al., 2019; Lee and Vargo, 2017). As physical activity and dance are relatively accessible to all, they may address some of the barriers associated with the more 'traditional' styles of therapy. Exercise interventions can be much more cost-effective than traditional therapies as they often do not need a highly trained specialist or require intense individual support. Moreover, physical activity can be performed in the home-, community-, or school-based environments with minimal equipment or specialised supervision needed (Bremer et al., 2016).

Alongside enhancing communication and language skills, there is also a desire to improve the physical health of autistic individuals as outlined by both Autistica and the National Health Service (Alderwick and Dixon, 2019; Autistica, 2018). Therefore, a better understanding of the available literature relating to coordinated movement for autistic children may benefit the design and implementation of evidence-based interventions; helping to not only support children's social development but also their physical well-being.

As a result, the purpose of this narrative review is to concentrate on the literature exploring physical activity, movement, dance, and communication skills in autistic children; pooling the available literature from interdisciplinary fields of research; such as psychology, sports psychology, neuroscience, and dance movement therapy into one coherent narrative review. A narrative review was deemed most appropriate, as the aim of this paper was to provide a broad overview of topic-related research fields. Furthermore, narrative reviews are often able to address multiple queries and synthesise a wealth of knowledge from several inter-disciplinary fields (Ferrari, 2015; Pae, 2015).

Firstly, the manuscript defines communication challenges in autistic children and delineates what is meant by dance and physical movement; often referred to as coordinated movement throughout this manuscript. Secondly, the benefits of coordinated movement for an autistic individual are narratively explored, before focusing on specific elements of dance movement therapy that may help to enhance communication skills. Finally, unlike many of the reviews available, this review explores the available evidence and theories that rationalise why these more naturalistic coordinated movement-based therapies are effective at enhancing social-communication skills in autistic children. The review provides suggestions for how specific components of coordinated-based interventions are underpinned by sound theory, allowing for real-world impact (Healy et al., 2018).

2. Methods

Due to the nature of this narrative review, a systematic methodology was not employed. However, similar to the methods used by Green et al. (2006) for a narrative review, the information used to write this paper was collected from the sources listed in Table 1.

3. Communication challenges in autism

Social communication challenges may encompass an array of 'non-typical' or limited social skills. For example, impairments in social-emotion linguistic reciprocity may involve abnormal social approach or failure of normal back-and-forth conversation, limited sharing of emotion, affect or interests, and failure to initiate or respond to social interactions. Deficits in paralinguistic or pragmatic communicative behaviours used for social interaction can involve a monotonous voice, abnormal eye contact, atypical body language, limited understanding of context, and minimal use of gestures or facial expressions. Many of these social communication idiosyncrasies are observed in ASD. As communication skills are key to developing and maintaining personal and professional relationships, difficulties in communication and social interaction can lead to both personal and professional difficulties, subsequently impacting QoL (Palmer et al., 2016; Wang et al., 2018).

As previously outlined, social communication challenges represent a core and often functionally impairing feature of ASD that are extensively relied on for its diagnosis. Generally, deviations in typical social development in an infant later diagnosed with autism are recognised by reduced frequency and diversity of communicative forms; including, complex babbling, gestures, consonants in syllables, words and word combinations (Landa, 2007; Ronconi et al., 2016; Vivanti et al., 2017). Furthermore, opening social-communicative interactions with others that require integrated attention to social and non-social aspects of the context is also often reduced in autistic children (Hess, 2006). As a result, autistic children may have a reduced repertoire by which to initiate conversation and indicate their needs or requests to others. Consequently, their effectiveness as communicators; initiating social bids and requests is perceived as limited in comparison to typically developing, age-matched peers.

Autistic children are often observed to show reduced joint attention during infancy; reflecting difficulty in coordinating attention between objects and people, or between multiple people – a key skill required during social interactions (Frith et al., 2003; Mundy and Crowson, 1997). Due to difficulties in joint attention,

Table 1
Sources used for this narrative overview.

Sources	Dates searched	Keywords used (relating to topics of narrative review)
PubMed	1970–2021	Autism, Autism Spectrum Disorder, Autistic
SPORTDiscus		Physical Activity, Exercise, Sport*, Co-ordinated Movement, Dance, Dance Movement
EBSCOhost		Therapy, Intervention
MEDLINE		Communication, Social Skills, Socia* Effect*, Benefic*,
Google Scholar		
Examination of the references included in retrieved and relevant articles	1970–2021	

children may struggle to use others' gaze cues in word learning tasks (Franchini et al., 2019) or use eye contact and eye gaze appropriately. It is also reported that early joint attention abilities are predictive of later language functioning and communication abilities in autism (Adamson et al., 2019; Poon et al., 2012). Therefore, if early joint attention can be enhanced in children diagnosed with autism at a young age, it may reduce later language impairments and improve communication for social interactions.

Akin to joint attention, imitation is a social skill that allows for social connectedness and emotional sharing between humans. It is described as a 'core human skill, which is critical for the development of both social interaction and practical knowledge' (pg. 279; Vivanti and Hamilton, 2014). For example, infant imitation allows a child to learn and explore other's actions and intentions; providing a vehicle for early communicative reciprocity (Landa, 2007). However, it is observed that children diagnosed with ASD often demonstrate impaired imitation abilities; displaying less frequent spontaneous imitation and relating to their social interactions (Hobson and Lee, 1999; Rogers et al., 2003). Additionally, a previous systematic review including 21 well-controlled studies involving 281 cases of ASD found that, overall, autistic children performed significantly worse on imitative tasks than non-autistic individuals (Williams et al., 2004), consequently affecting their sensory and motor capabilities. Therefore, it may be inferred that poor imitation skills somewhat hinder communication skills and limit social interaction (Dadgar et al., 2017; Pusponegoro et al., 2016). Nonetheless, it is anticipated that autistic children often have deficient, not absent, imitation skills. Their ability to imitate objects and goal-directed imitation often remains relatively intact (Edwards, 2014; Sowden et al., 2016; Vivanti and Hamilton, 2014). Therefore, highlighting a potential target for therapeutic intervention to enhance and improve pre-existing skills.

Although autistic children may not possess 'typical' communication skills, they can still utilise and develop their own means of communication. Subsequently, routes should be explored to enhance autistic children's own form of communication and not just characteristic or neurotypical forms of communication. For example, children diagnosed with ASD may use various behaviours; such as, stereotypy, aggression, or even self-injury in an attempt to communicate. Research suggests that up to 80% of 'challenging' behaviours may have a communicative function, demonstrating these behaviours are not meaningless (Goldstein, 2002; Watkins et al., 2017). Instead, they have a vital function for a significant number of autistic children. Resultantly, interventions focused on reducing challenging behaviours should also aim to provide an alternative means of communication for autistic children to still feel they have a voice.

4. Physical activity as a therapeutic intervention in autism

Coordinated movement and physical activity; whereby movement of the limbs is coordinated via motor control and energy is required, may offer an exciting vehicle to enhance joint attention abilities, imitation capabilities, and social-communication development, whilst reducing behaviour that challenges. Thus, offering autistic children the opportunity to develop their own voice and enhance how they communicate.

Research has increasingly investigated how coordinated movement and physical activity can be used as effective interventions to reduce functionally impairing symptoms associated with ASD. Several systematic reviews have recently been published highlighting the potential strength of interventions that involve coordinated movement and physical activity for improving outcomes in autistic individuals; including Chan et al. (2020), Howells et al. (2019), and Sam and Tong (2015). Overall, involvement in physical activity and coordinated movement appears to positively influence the primary areas associated with ASD, including social skills and repetitive movements. As enhancing communications skills and social development is an important research priority for the autistic community (Autistica, 2016), we now explore and narratively review various studies investigating physical activity and coordinated movement as interventions targeting social-communicative outcomes for autistic children (Table 2).

Some of the earliest research, demonstrating that physical activity may improve functional outcomes in autistic children, was completed by Watters and Watters in the early 1980s. They reported that performing regular aerobic exercise for 8-min reduced self-stimulating behaviour; such as rocking, pacing and hand flapping in five-to six-year-old children diagnosed with ASD (Watters and Watters, 1980). Although the authors did not investigate the effect of aerobic activity on communication skills, the study highlighted the early potential of coordinated movement for addressing some of the potential traits associated with ASD.

Zachor et al. (2017) conducted a controlled trial with 51 autistic children. 30 participants completed an outdoor adventure programme for 13 weeks involving challenging physical activities. The activities; such as a climbing a two-way rope ladder and conquering a rope bridge, all required the children to communicate with their programme instructors and peers. Another 21 participants acted as a control group and did not partake in the adventure programme. The results revealed significant improvements in social-communication and opposing directions of change in the two groups for social cognition, social motivation, and autistic mannerisms subdomains of the Social Responsiveness Scale (Constantino et al., 2003). The intervention group receiving the outdoor adventure programme showed a significant propensity towards decreased ASD-symptom severity, whilst the control group showed an increase (Zachor et al., 2017). Thus, highlighting the positive benefits of physical activity for social skills.

Similarly, Toscano et al. (2018) examined the effects of a 48-week exercise-based intervention on the psychosocial health of autistic children in a randomised controlled trial. The authors reported a substantial improvement in children's psychosocial health score as measured by the Child Health Questionnaire (Raat et al., 2002) following the exercise-based intervention. Despite the robustness of a randomised controlled trial protocol, the study

Table 2
Brief overview of primary studies included in the narrative review, relating to physical activity for autistic individuals; including, studies' authors, title, characteristics, and conclusions drawn from research.

Authors	Title	Study Design	Participants	Intervention	Conclusion
Bass et al. (2009)	The effect of therapeutic horseback riding on social functioning in children with autism.	Randomised controlled trial.	34 autistic children, aged between 4 and 10 years old.	Experimental group (n = 19) were assigned 12 weeks of therapeutic horseback riding. Control group (n = 15) were placed on a 12-week waitlist.	Autistic children participating in therapeutic horseback riding showed greater sensory seeking and sensitivity, improved social motivation, and less inattention and distractibility than that of the control group.
Best and Jones (1974)	Movement Therapy in the Treatment of Autistic Children.	Within-participant repeated-measures study.	4 autistic children, aged between 2 and 4 years old.	Children participated in 30 min of swimming and water aerobics activities for 10 weeks.	Improvements in gross-motor behaviour whilst in the water were reported. Furthermore, improvements in social functioning and vocabulary were also noted.
Borgi et al. (2016)	Effectiveness of a Standardized Equine-Assisted Therapy Program for Children with Autism Spectrum Disorder.	Randomised controlled trial.	28 autistic children, aged between 6 and 12 years old.	Experimental group (n = 15) completed 6 months of once-weekly equine-therapeutic sessions; consisting of structured activities including work on the ground and horse riding. Control group (n = 13) were placed on a waitlist.	Autistic children in the experimental group showed an improvement in social skills and a mild effect on motor abilities compared to the control group. Improved executive functioning was also observed at the end of the equine-therapeutic sessions.
Chu and Pan (2012)	The effect of peer- and sibling-assisted aquatic program on interaction behaviors and aquatic skills of children with autism spectrum disorders and their peers/siblings.	Controlled trial.	21 autistic children and 21 typically developing children. All children aged between 7 and 12 years old.	Participants were assigned to three groups: peer-assisted group sibling-assisted group, and control group. In each group there were 7 autistic children and 7 typically developing children. All children complete a twice-weekly after-school aquatic program for 16 weeks.	Autistic children in the peer-assisted group and sibling-assisted group showed significantly more improvements on physical and social interactions compared to children in the control group. All groups improved their aquatic skills.
Güeita-Rodríguez et al. (2021)	Effects of Aquatic Therapy for Children with Autism Spectrum Disorder on Social Competence and Quality of Life: A Mixed Methods Study.	Mixed methods intervention study.	6 autistic children, aged between 6 and 12 years old.	Children completed Water Specific Therapy Halliwick sessions twice a week for over seven months.	Results showed statistically significant increases in perceived physical competence and aquatic skills, alongside improvements in social acceptance and advances in school functioning.
Pan (2010)	Effects of water exercise swimming program on aquatic skills and social behaviours in children with autism spectrum disorders.	Within-participant repeated-measures study (A-B design).	16 autistic children, aged between 6 and 9 years old.	Children completed a 10 week water exercise swimming program intervention consisting of 20 sessions; twice per week. The A-group (n = 8) completed 10 sessions first, then the B-group (n = 8) completed 10 sessions.	Results indicated that water exercise and swimming sessions improved aquatic skills in the participants; holding potential for social improvements as children showed a decrease in antisocial behaviours following the aquatic program.
Toscano et al. (2018)	Exercise Effects for Children With Autism Spectrum Disorder: Metabolic Health, Autistic Traits, and Quality of Life.	Randomised controlled trial.	64 autistic children, aged between 6 and 12 years old.	Experimental group (n = 46) were exposed to a 48-week exercise-based intervention; involving coordination and strength exercises. Control group (n = 18) continued with treatment as usual and maintained their usual levels of daily activity, without additional exercise components.	Children participating in the exercise-based intervention showed greater positive effects in their improved metabolic health and reduced autistic traits relative to the control group. Parents' perceptions of their children's quality of life also significantly increased more so for those in the intervention group, in comparison to those in the control group.
van den Hout and Bragonje (2010)	The effect of equine assisted therapy in children with autism spectrum.	Within-participant repeated-measures study.	60 autistic children, aged between 2 and 14 years old.	Children participated in once-weekly equine assisted therapy sessions for 10 weeks.	A significant improvement in autism severity was observed for children following 10 weeks of equine-assisted therapy. Effects on specific areas of functioning measured were all significant, with the most positive effects on sociability and sensory/cognitive awareness.
Vonder Hulls et al. (2006)	Clinicians' perceptions of the benefits of aquatic therapy for young children with autism: A preliminary study.	Qualitative survey study.	18 aquatic occupational therapists treating young autistic children (aged between 4 and 10 years old).	Participants responded to a survey requesting their opinions on changes observed in skill performance as a consequence of aquatic therapy.	All of the therapists surveyed indicated an increase in skill performance for tolerating touch, initiating and maintaining eye contact, and concentrating or paying attention. The most frequently reported benefits ranged from improving physical skills (e.g., improved strength, balance) at the body's functional level to increasing social participation.
Watters and Watters (1980)	Decreasing self-stimulatory behaviour with physical exercise in a group of autistic boys.	Within-participant repeated-	Five autistic children aged between 9 and 11 years old.	Children participated in 27 language training sessions. After each session, one of three conditions followed: (1)	It was found that the lowest levels of self-stimulation followed the physical exercise condition. However, no

(*continued on next page*)

Table 2 (*continued*)

Authors	Title	Study Design	Participants	Intervention	Conclusion
		measures study.		Physical exercise (8–10 min of jogging), (2) TV watching, or (3) regular academic work.	differences were found between conditions for accurate question answering.
Yilmaz et al. (2004)	Effects of swimming training on physical fitness and water orientation in autism.	Case study.	1 autistic child, aged 9 years old.	The child completed a water based programme based on the Halliwick method. Completing three sessions per week for 10 weeks.	The results showed that swimming training and water exercises were effective for the development of physical fitness and water orientation capabilities for the autistic participant. Stereotypical movements (spinning, swinging and delayed echolalia) also decreased.
Zachor et al. (2017)	The effectiveness of an outdoor adventure programme for young children with autism spectrum disorder: A controlled study.	Controlled trial.	51 autistic children, aged between 3 and 7 years old.	Experimental group (n = 30) participated in a 13-week outdoor adventure programme, completing weekly challenging physical activities. Control group did not participate and continued as normal.	Children in the experimental group showed a significant improvement in social communication skills; social cognition, social motivation, and autistic mannerisms, in comparison to the control group.
Zhao and Chen (2018)	The Effects of Structured Physical Activity Program on Social Interaction and Communication for Children with Autism.	Randomised controlled trail.	50 autistic children, aged between.	The experimental group (n = 25) completed a 12-week structured physical activity program consisting of 24 exercise sessions, which targeted social interaction and communication.	Results showed an overall improvement in social skills and social interaction for the experimental group and improvements were also observed in communication, cooperation, social interaction, and self-control. However, no changes were observed for the control group.

relied on parental perception of their child's profile changes. Therefore, future research may attempt to include complementary data from direct observations in their methods, alongside parent-reported measures.

Zhao and Chen (2018) implemented a 12-week structured physical activity program, which included 24 exercise sessions focusing on social interaction and communication with 41 children diagnosed with ASD. Both the Assessment of Basic Language and Learning Skills-Revised (Partington, 2008), and the Social Skills Improvement System Rating Scales (Gresham and Stephen, 2007) revealed statistically significant improvements in social interaction and social skills across the experimental group between pre- and post-programme results. Significant advances were also reported in communication, cooperation, social interaction, and self-control subdomains. This study demonstrated the benefits of coordinated movement in enhancing communication and social-communicative skills of autistic children. However, in the absence of a retention test, it is not clear whether the observed results were temporary or permanent. It would be interesting to conduct a similar study and include a follow-up study after the structured physical activity program to assess if improvements were transient. Nonetheless, the previous studies all provide support for coordinated movement as an important therapeutic intervention for autistic children targeting social development.

Alongside more linear forms of physical activity such as running and aerobic activity, the implementation of physical activity programmes concerning water aerobics has shown several beneficial effects in children who had a diagnosis of autism (Best and Jones, 1974; Pan, 2010; Yilmaz et al., 2004). For example, in a sample of autistic children (n = 4), the therapeutic use of water activities was found to support language development and facilitate self-concept, which are vital skills for effective communication (Best and Jones, 1974). However, this early study was conducted within a small sample size, thus limiting its clinical significance. Since, a 10-week water exercise swimming program including 16 autistic boys was observed to produce significant improvements in aquatic skills and social-communicative behaviours as rated by the children's teacher using the School Social Behaviour Scales (Pan, 2010). Therefore, supporting the benefit of swimming for autistic children in a larger sample size.

Similarly, Chu and Pan (2012) reported that peer- or sibling-assisted swimming twice a week for 16 weeks improved social behaviours and social functioning in 21 autistic children. Subsequently, emphasising the successful use of swimming as a promising vehicle to enhance communication skills in autistic individuals. More recently, a multi-method study was conducted to evaluate the effects of swimming and aquatic therapy on autistic children's social competence and quality of life (Güeita-Rodríguez et al., 2021). The study involved six children completing two 60-min aquatic therapy sessions per week, for seven months. The results revealed statistically significant improvements in social and physical competence; further promoting the important implications of aquatic programs and interventions for improving social outcomes in autistic children.

A pilot study was also conducted amongst occupational therapists, who often used water aerobics when working with autistic children and their families, to gain a greater understanding of the benefits of aquatic therapy from a clinician's perspective and the use of aquatic-based interventions for autistic children (Vonder Hulls et al., 2006). Importantly, the most frequently reported benefits were improved performance in underlying skills at the body's functional level and increased social participation; where the majority of therapists noted an improvement in eye contact, conversation skills, play skills, and turn-taking skills following aquatic therapy. The study demonstrated the successful integration of swimming and aquatic-based therapy into practice, highlighting positive social-communicative outcomes for autistic children outside of the scientific literature.

In addition to water-related physical activity, equine-related coordinated movement has also been observed to have positive impacts for autistic children. van den Hout and Bragonje (2010) employed a large study examining the effect of horse riding in 60 autistic children on the overall severity of ASD and specific areas of functions (sociability, communication, sensory/cognitive awareness, and physical behaviour). Results indicated that equine-assisted therapy significantly decreased ASD severity, correlating with the quantity of horse riding lessons. Moreover, significant improvements in all areas of functioning were observed, with particularly large effects noted in sociability and sensory/cognitive awareness (van den Hout and Bragonje, 2010). However, the

authors did not employ a control group. Therefore, the effects observed in the study cannot definitively be attributed to treatment effects. Bass et al. (2009), also explored the benefits of therapeutic horseback riding on social functioning in autistic children; however, they did employ a between-group comparison of the experimental group (n = 19) and control group (waiting-list, n = 15). Bass et al. (2009) reported that horse riding for autistic children was associated with greater sensory seeking and social motivation, less inattention, distractibility and sedentary behaviours. As a result, equine-related coordinated movement may be a potentially efficacious intervention for autistic children.

More recently, Borgi et al. (2016) further supported the notion of therapeutic riding as a complementary intervention strategy for autistic children by conducting a randomised controlled trial. Children who participated in the 6-month equine-assisted therapy showed a time-dependent improvement in social functioning compared to the waitlist control group. However, Borgi et al. (2016) noted a limitation of their study were the differing baseline scores in some of the domains assessed between groups, which subsequently could have impacted the post-intervention scores. Therefore, the study may have benefited from matching participants before randomly assigning them to their groups. Nonetheless, the results observed fall in line with previous research demonstrating that the most frequently reported outcome of equine-assisted programs for autistic children was an improvement in social motivation and capabilities (Harris and Williams, 2017; KEINO et al., 2009; Lanning et al., 2014; Srinivasan et al., 2018).

5. Dance as a therapeutic intervention for autism

Dance is a type of physical activity or coordinated movement that exists in the form of art, usually consisting of purposefully selected sequences of human movement requiring the coordination of different muscles. Dance teaches the importance of movement and fitness in a variety of ways, yet also allows one to express feeling and emotion through the use of rhythm and body positions (Calvo et al., 2015; Camurri et al., 2003). More recently, dance has been used as a therapy to help several physical and psychological conditions; including, depression (Karkou et al., 2019), Parkinson's disease (de Natale et al., 2017; dos Santos Delabary, M et al., 2018) and cancer (Ho et al., 2016). As defined by the American Dance Therapy Association (ADTA), dance movement therapy (DMT) is the psychotherapeutic use of movement to promote emotional, social, cognitive and physical integration of the individual, for the purpose of improving health and well-being (ADTA, 2009).

Increasingly, dance has been shown to improve communication skills in various populations. In a group of high school females, attending weekly dance classes improved communication skills and allowed participants to communicate in their own style (Corteville, 2009). Further, von Rossberg-Gempton et al. (1999) found that creative dance improved children's communication skills, cooperation skills, and awareness of others. The authors suggested that creative dance and coordinated movement encouraged a bond between children through the sharing of ideas and physical space, and the acceptance of individual differences, leading to increased communication skills. Similarly, a study conducted by Lobo and Winsler (2006) provided strong scientific evidence to support the use of dance and creative movement programs in early childhood for the improvement of social skills. Therefore, dance seems an excellent form of coordinated movement to enhance social development and improve communication skills for autistic children.

Outside of the scientific literature, dance movement therapy therapists have consistently worked with autistic individuals; reporting promising results through the successful use of mirroring, synchronous movement interaction, and rhythm to encourage connection and communication (Martin, 2014; Cozolino, 2014; Tortora, 2005). Before verbal language develops, infants and young children usually communicate through their bodies, using gestures and movements. For that reason, DMT is well suited to working with autistic children as it provides a holistic approach that incorporates the body and mind, thriving in the non-verbal realm of communication (Martin, 2014). Consequently, DMT focuses on a child's functioning in terms of body awareness, timing and rhythm, motor coordination, and social/communicative development. It is unsurprising, therefore, that DMT interventions may provide a potential pathway to integrate and enhance motor and social/communicative skills, which are reduced in autistic children. We now explore and narratively review the literature associated with dance movement therapy as an intervention for autistic individuals (Table 3).

A recent systematic review highlighted seven studies, which were published between 1970 and 2018, focusing on the use of DMT for autistic individuals (DeJesus et al., 2020). Whilst many positive outcomes were observed for social development and communication skills, the authors concluded that future research should strive for greater scientific rigour in documenting the efficacy of DMT treatment interventions for autistic individuals; attempting to improve the reliability and reproducibility of findings. Furthermore, only two of the seven studies included in the systematic review comprised only of autistic children. Nonetheless, DeJesus et al. (2020) reiterated the importance of both mirroring and rhythm during DMT for enhancing social skills in autistic individuals.

Siegel (1973) described working with four autistic children between the ages of 4 and 6 year olds in a nursery. Each child completed a nine-month intervention of DMT, which aimed to promote positive body-image building and an improved sense of 'self'. Siegel (1973) reported positive responses from the children and highlighted the use of verbal and non-verbal communication to encourage mirroring and reduce aggressive behaviours. Similarly, Boettinger (1978) explored mirroring in autistic children aged between 3 and 9 years old during movement therapy. The author reported an increase in synchronous movement and communicative gestures, alongside a decrease in touch-aversion. Importantly, this study only included autistic girls, who are often underrepresented in the scientific literature, subsequently emphasising that coordinated movement can be beneficial for both autistic boys and girls .

Hartshorn et al. (2001) implemented two, 30-min DMT-inspired sessions per week for 2 months for 38 autistic children. Results from the study demonstrated significant increases in attentive and on-task behaviours and a decrease in stress behaviours via behavioural observation. Further highlighting the utility of DMT for autistic children. More recently, Samaritter and Payne (2017) investigated the use of DMT to elicit changes in interpersonal movement behaviours in four young autistic children. Results were summarised into a movement observation scale termed the 'Social Engagement and Attunement Movement' (SEAM) scale. The authors reported positive increases in SEAM behaviours, attributing these improvements to social attunement. However, the small sample size and use of a novel observation measure somewhat limits the generalisability and validity of the findings. Nonetheless, the aforementioned studies suggest dance and coordinated movement are effective vehicles for enhancing social-communicative behaviours in autistic children.

Recently, studies employing larger sample sizes and grounded in the 'gold-standard' of research methods - randomised control trials, have all demonstrate that dance can have positive effects for autistic individuals (Hildebrandt et al., 2016; Mastrominico et al.,

2018; Souza-Santos et al., 2018). For example, Hildebrandt et al. (2016) demonstrated that participation in twice-weekly dance sessions helped to reduced impairing traits associated with ASD in comparison to not participating in any dance sessions. Furthermore, Koehne et al. (2016a) demonstrated in an active-control trial, that participation in dance-based programme significantly improved emotion inference and synchronisation for autistic individuals in comparison to participation in an individual motor coordination programme. However, more work is needed to provide a scientific evidence base for the efficacy of using DMT as an early intervention for ASD, especially for autistic children as most available DMT studies appeared to include only adolescents and adults.

5.1. Element of mirroring within dance movement therapy

Mirroring is a key element regularly used during DMT; involving the teacher or dance movement therapist copying the exact shape, form, movement qualities and feeling of another's actions during DMT. This technique can be used to help create a connection between a therapist and child, alongside developing meaningful imitation skills and social engagement. Several studies have demonstrated mirroring as an effective feature for enhancing communication skills in autistic individuals (Hartshorn et al., 2001; Koch et al., 2015). For example, Field et al. (2001) demonstrated that autistic children who were repeatedly mirrored by an adult in three sessions showed greater social behaviours in comparison to autistic children who simply played with the adult during the same sessions.

Additionally, studies focusing on mirroring interventions in autistic individuals describe effects on the sensory-motor regulation of the subject, as well as social interaction with the environment and/or teacher/dance movement therapist (Hartshorn et al., 2001; Koch et al., 2015). As result, it appears that mirroring and imitation activities can be used to promote meaningful social skills and social interaction in autistic children.

5.2. Element of timing and rhythm within dance movement therapy

Timing and rhythm is another key element used within DMT. The element of rhythm involves attending to not only external rhythms but also internal rhythms and can serve as a non-verbal unifier between individuals. Within DMT, the therapist may address the individual's ability to synchronise with external rhythms of their environments or internal rhythms such as their heartbeat. Importantly, attending to rhythm and the ability to synchronise with others has been associated with improved social outcomes. Where interpersonal motor synchrony to musical rhythms serves as a vehicle to increase social bonds between social partners (Hove and Risen, 2009; Morris et al., 2021; Tordjman et al., 2015; Valdesolo and Desteno, 2011). During such interventions, the leader or dance movement therapy therapist often utilises rhythm to attune to the autistic individual; helping to organise their feelings and facilitate interaction and communication. Whilst there is limited evidence focusing on rhythmicity in DMT with autistic children, many dance movement therapy therapists report rhythm as a fundamental element of DMT (Amos, 2013; Behrends et al., 2012; Berlandy, 2019; Morris et al., 2021). Further, the use of rhythm has been extended to music-based interventions (Sharda et al., 2018) and rhythm-based interventions including dyadic drumming (Willemin et al., 2018; Yoo and Kim, 2018), which have all demonstrated successful positive changes in social skills in autistic children.

6. How coordinated movement alleviates some traits associated with autism

The exact mechanism for how coordinated movement improves communication and other facets associated with autism are not yet clear. However, a possible explanation for the benefits of physical activity on social interaction and communication in autistic children is that physical activities often encompass a natural setting to promote positive social interactions; such as during sport or DMT (Lee and Vargo, 2017). It provides a vehicle to build successful relationships between the instructor and participants and also between the participants themselves in group settings. Additionally, physical activity, movement, and dance provide several opportunities for interpersonal interaction, offering an ideal medium to engage in cooperative play, partnering for teamwork, and communication, which all benefit social skills and development (Lee and Vargo, 2017).

Possible explanations for reducing stereotypical and repetitive behaviours; allowing time for communication skills to develop, involve the idea of fatigue and automatic reinforcement. It is believed that fatigue, resulting from increased exercise, leads to decreased stereotyped behaviours (Lang et al., 2010). Alternatively, in some children, physical stimulation obtained through coordinated movement may be similar to that gained through stereotypy. It is hypothesised that repetitive and stereotypical behaviours; such as rocking and arm flapping, are performed as it produces a pleasant internal outcome for the individual (automatic reinforcement; Rapp et al., 2004). As coordinated movements can include similar body movements that are observed in stereotypy or stimming, it may produce similar internal states in the individual and fulfil their need for automatic reinforcement (Lang et al., 2010). For example, repeating the same dance movements rhythmically to a piece of music may reduce the desire to produce stereotypic movements in the near future for that child. Similarly, higher levels of stereotypy have previously been associated with more significant impairments in social functioning in autistic children (Lanovaz et al., 2013). Therefore, a reduction in functionally impairing stereotypy may help to improve social outcomes by providing greater opportunities for and engagement in social development.

Zhao and Chen (2018) noted improved communication following their physical activity program, which incorporated the TEACHH model (Panerai et al., 2002). The TEACHH model is one of the most validated interventions used when working with autistic individuals and incorporates physical structure, visual schedule cards and cues, and work systems. Zhao and Chen (2018) incorporated the structured instruction of the TEACCH model as a beneficial treatment strategy for facilitating language development; subsequently creating an environment that positively influenced the children's communication skills. Furthermore, Zhao and Chen (2018) ensured the integration of elements that created more opportunities for communication into their physical activity program. For example; both teachers and volunteers were required to ask simple questions, encouraging the participants to answer and become active communicators. Additionally, the program had a reward scheme to motivate the participants to engage in the activities program. Without realising, the children began to respond, with “thank you” or “bye-bye” and initiating eye contact to receive the reward (Zhao and Chen, 2018). Akin to Pan (2010), Zhao and Chen (2018) attributed the success of their program in increasing communication and social competence to the limited instructor to child ratio (1:5). Therefore, highlighting the need for small groups and a low instructor to child ratio to ensure the success of physical activity interventions for autistic children.

Swimming and aquatic-based physical activity programmes were observed to cause a reduction in antisocial behaviours and an

Table 3
Brief overview of primary studies included in the narrative review, relating to dance and elements of dance movement therapy for autistic individuals; including, studies' authors, title, characteristics, and conclusions drawn from research.

Authors	Title	Study Design	Participants	Intervention	Conclusion
Field et al. (2001)	Children with Autism Display more Social Behaviours after Repeated Imitation Sessions.	Randomised parallel group trial.	20 autistic children, aged between 4 and 6 years old.	Children were either repeatedly exposed to an imitation condition (n = 10), where unfamiliar adults imitated their behaviour or they were exposed to a contingently responsive condition (n = 10), where adults responded to their behaviour but did not imitate them.	Distal and proximal social behaviours were observed to increase in children who were repeatedly exposed to adult imitation, in comparison to children in the contingently responsive group. Furthermore, solitary behaviours of children in the imitation group; including, inactivity and playing alone, decreased as the sessions progressed.
Hartshorn et al. (2001)	Creative Movement Therapy Benefits Children with Autism.	Controlled trial.	76 autistic children, aged between 3 and 7 years old.	Children in the intervention group (n = 38) completed twice-weekly movement sessions for 2 months, whereas the control group (n = 38) continued with treatment as usual.	Following a 2 month period, children in the intervention group spent less time wandering and more time showing on-task behaviour than the control group. Furthermore, children who participated in the movement sessions also spent less time showing negative responses to being touched and resisting the teacher.
Hildebrandt et al. (2016)	We Dance and Find Each Other'1: Effects of Dance/Movement Therapy on Negative Symptoms in Autism Spectrum Disorder.	Randomised controlled trial.	78 autistic individuals, aged between 14 and 65 years old.	The study was subdivided into three consecutive rounds of the intervention within a two-year timeframe. Participants were randomly assigned to one of the three groups, one of which formed the waiting control group. The intervention group (n = 55) participated in ten weekly sessions of manualised dance movement therapy, whilst the control group (n = 23) continued with treatment as usual.	A marginal significant reduction in the overall negative symptoms experienced by autistic individuals was greater in the treatment group than for the control group.
Koch et al. (2015)	Fixing the mirrors: A feasibility study of the effects of dance movement therapy on young adults with autism spectrum disorder.	Controlled trial.	31 autistic individuals aged, between 16 and 47 years old.	Individuals in the intervention group (n = 16) completed 7 weeks of a manualized dance movement therapy program once a week. The control group (n = 15) did not participate in the intervention.	Participants in the intervention group reported improved well-being, improved body awareness, improved self–other distinction, and increased social skills relative to the control group.
Koehne et al. (2016a)	Fostering Social Cognition through an Imitation- and Synchronisation-Based Dance/Movement Intervention in Adults with Autism Spectrum Disorder: A Controlled Proof-of-Concept Study.	Controlled trial.	55 autistic individuals, aged between 18 and 55 years ol.d	Individuals in the intervention group (n = 27) received a dance/movement intervention focusing on interpersonal movement imitation and synchronisation. Individuals in the control group (n = 24) received a controlled movement intervention focusing on individual motor coordination. Both occurred for 10 weeks.	Participants in the intervention group showed a significantly larger improvement in emotion inference than those in the control group, but this was not apparent for empathic feelings. Generally, the intervention group showed increased synchronisation skills and imitation tendencies, relative to the control group.
Mastrominico et al. (2018)	Effects of Dance Movement Therapy on Adult Patients with Autism Spectrum Disorder: A Randomized Controlled Trial.	Randomised controlled trial.	57 autistic individuals, aged between 14 and 15 years old.	Participants in the intervention group (n = 35) participated in a 10-week manualised dance movement therapy intervention, whereas the control group (n = 22) only received the intervention after a waiting period.	Although participants in the intervention group showed improvements in empathy, cognitive empathy, and mirroring abilities, these were not great than that of the control group.
Morris et al. (2021)	Dance, rhythm, and autism spectrum disorder: An explorative study.	Mixed methods survey study.	113 registered dance and movement therapists, aged not reported.	Participants responded to a survey requesting their opinions on rhythm and music used with dance movement therapy sessions with autistic children.	The most common features of music and rhythm therapist used within their sessions with autistic children included a 4/4 time signature, moderato tempo, and the inclusion of age-appropriate pop lyrics. Furthermore, dance movement therapists highlighted that rhythm and attending to rhythm were integral parts of their sessions with autistic clients.
Samaritter and Payne (2017)	Through the Kinesthetic Lens: Observation of Social Attunement in Autism Spectrum Disorders	Mixed-method, multiple case study.	4 autistic children, with a mean age of 12.2 years old.	Children participated in dance movement therapy sessions in an outpatient clinical setting and sessions were recorded.	Findings were summarised into an observation scale for interpersonal movement behaviours. Results showed a positive increase in interpersonal and social attunement behaviours between the first and fourth (final) recordings.
Sharda et al. (2018)	Music improves social communication and auditory-motor connectivity in children with autism.	Randomised controlled trial.	51 autistic children, aged between 6 and 12 years old.	The intervention group (n = 26) received 8–12 weeks of music sessions involving use of improvisational approaches through song and rhythm. The control	Communication scores were higher in the intervention group post-intervention compared to control group. Furthermore, post-intervention

(*continued on next page*)

Table 3 (*continued*)

Authors	Title	Study Design	Participants	Intervention	Conclusion
				group (n = 25) were exposed to a structurally matched behavioural intervention with no music.	brain connectivity was lower between auditory and visual regions in the intervention group compared to the control groups, often over-connected in autism. This lower brain connectivity was associated with improved communication for the intervention group.
Souza-Santos et al. (2018)	Dance and equine-assisted therapy in autism spectrum disorder: Crossover randomized clinical trial.	Randomised controlled trial.	45 autistic participants, aged between 5 and 12 years old.	Children were allocated to one of three groups and received 24 bi-weekly sessions in each group across 12 weeks. Children in the dance group (n = 15) completed the 'TALT' dance programme. Children in the equine-assisted therapy group (n = 15) completed tasks including horse approach, touch stimulation, and horse riding with various courses. Children in the dance and equine-assisted group completed both dance classes and equine-assisted therapy sessions once a week.	Only the dance group showed a significant improvement in functional independence and more specifically, communication and psychosocial adjustments. Significantly greater improvements in classification of functioning was observed in the dance & equine-assisted therapy group.
Willemin et al. (2018)	Social Emotional Effects of Drumtastic®: A Dyadic within-Group Drumming Pilot Program for Children with Autism Spectrum Disorder.	Within-participant repeated-measures study.	14 autistic children, aged between 5 and 14 years old.	Children participated in 8 biweekly sessions of a novel dyadic drumming program called 'Drumtastic' across a four-week summer camp.	Improvement in the domains of enjoyment and fun were observed following the intervention. Children also showed a positive improvement in developing social relationships with their peers and staff at the summer camp.
Yoo and Kim (2018)	Dyadic Drum Playing and Social Skills: Implications for Rhythm-Mediated Intervention for Children with Autism Spectrum Disorder.	Within-participant repeated-measures study.	8 autistic children with a mean age of 10.8 years old.	Each participant received a total of 8 individual dyadic drumming sessions. The intervention consisted of three stages: engagement, interpersonal coordination, and modulation.	Social skills of children participating in the rhythm-mediated music therapy intervention improved their social skills, more specifically their cooperation and self-control skills. Furthermore, participants showed decreased asynchrony when tapping with a partner and greater engagement in joint action following the intervention.

increase in social behaviours (Pan, 2010; Chu and Pan, 2012; Yilmaz et al., 2004). All children, not only those diagnosed with ASD, can benefit from watching positive social interactions of others. During the ASD swimming programmes, training and instructions were repeatedly given in very small groups (Pan, 2010; Chu and Pan, 2012). Furthermore, social interaction between the instructor and the children's peers were reinforced; for example, facilitating sharing exchanges, encouraging children to seek assistance from each other, and waiting in line for a turn. Additionally, the importance of instructors should be highlighted. During the study conducted by Pan (2010), the instructor to child ratio was 1:2. Each instructor had to physically guide their children through movement, explaining and demonstrating actions when the children did not understand, all whilst providing positive feedback (Pan, 2010). A favourable response to the individualised instruction could have increased motivation and enhanced competence, leading to increased social skills in the children and the development of positive relationships.

6.1. Mirroring

When looking at the specific elements of DMT, mirroring appears to show a strong relationship between activity and social-communicative development (Fitzpatrick, 2018; Koch et al., 2015; McGarry and Russo, 2011; Morris et al., 2021). Further, a significant association exists between mirroring ability and early social communication in young autistic children (Hanika and Boyer, 2019). Therefore, social motor synchronisation and mirroring may be important pathways to explore for understanding the social characteristics of autistic individuals.

Using the body and effective coordinated movement, DMT attends to difficulties in emotional understanding and cognition (Shuper Engelhard and Vulcan, 2021). By mirroring the autistic child's movements and applying empathic reflection, DMT helps to create an understanding relationship between the child and dance movement therapist; enhancing emotional awareness of oneself and others (Devereaux et al., 2012; Fuchs and Koch, 2014). It is believed that these simple, non-verbal interactions in an enriching, trusting, and protected environment aids in the development of successful communicative relationships both during the DMT session and during usual social interactions (Baron-Cohen and Wheelwright, 2004; Shuper Engelhard and Vulcan, 2021). This is further supported by the notion that shared understanding between individuals is generated ahead of speech, through body movements, physical responses, and non-verbal vocalisation (Delafield-Butt et al., 2020). As such, the paralinguistic and pragmatic features of an interaction establish the foundation of later, linguistic communication. Thus, social communication is improved through the basic therapeutic modality of reciprocal and creative mirroring and motor synchrony.

Previous research suggests that pathways involved in the beneficial effects of social synchronisation and mirroring may include the role and function of the Mirror Neurone System (MNS; di Pellegrino et al., 1992; Rizzolatti and Arbib, 1998). Essentially, the MNS describes neurones that are believed to become activated both when an individual is watching a movement/performance and when they are performing the movement themselves (Rizzolatti and Craighero, 2004). Therefore, the activation of the neurones in

each individual somewhat mirrors each other – owing to the name mirror neurones. It is proposed that this system underlies our understanding, or simulation, of other people's actions, which may even extend to understanding the emotions of others and showing empathy (Berrol, 2006; Iacoboni and Dapretto, 2006).

Since the discovery of the MNS, it is recognised that there is a network of areas involved in its functioning, including the pars opercularis of the inferior frontal gyrus and its neighbouring ventral area, which are activated during the observation and imitation of an action (Fitzpatrick, 2018). However, in autistic children it has been proposed that the MNS is somewhat impaired and reduced activations of the MNS have been observed – this is known as the '*Broken Mirror Theory of Autism*' (Becchio and Castiello, 2012; Dapretto et al., 2006; Iacoboni and Dapretto, 2006; Oberman and Ramachandran, 2007). The Broken Mirror Theory may provide some answers to why atypical imitation skills are observed in autistic children. For example, reduced activity of the MNS is hypothesised to arise from limited social engagement; inferring that increased social engagement may lead to repaired functioning of the MNS (Becchio and Castiello, 2012). DMT utilises mirroring and engages the MNS, which may subsequently increase empathy, reciprocal behaviours, and social interactions between the teacher/dance movement therapy therapist and autistic individual (McGarry and Russo, 2011; Berrol, 2006). Furthermore, if mirroring is performed at an early age in ASD it may result in better communication skills and social interactions as the child develops (Martin, 2014). However, the Broken Mirror Theory of autism is not without its critics. Some researchers have since demonstrated that regions of the brain believed to contain mirror neurones show the same pattern of brain activity in both autistic children and typically developing children (Dinstein et al., 2010; Fan et al., 2010; Hamilton et al., 2007). Furthermore, a recent review of the role of mirror neurones concluded that there was no compelling evidence to suggest that autism is associated with mirror neuron dysfunction (Heyes and Catmur, 2021). Overall, some researchers describe the evidence for a direct, causal relationship between the MNS regions of the human brain and the social difficulties observed in autism as weak (Southgate and deHamilton, 2008). However, the degree to which activity in the MNS is preserved in autistic individuals may be associated with the individual's symptom severity; as such autistic individuals may not have a global deficit within the MNS, instead, they may have deficits within specific nodes of the MNS, somewhat relating to their presentation (Fan et al., 2010; Kana et al., 2011). This may also give rise as to why some imitation skills are preserved in autistic individuals and others are not. Despite the Broken Mirror Theory of autism gaining much criticism over the years and seemingly not offering a direct, causal relationship between neurobiology and the social challenges autistic individuals face, it presents a neurocognitive model of social behaviour that can be further explored and improved in order to understand the direct and indirect causes of social communication challenges in ASD.

Mirroring and the process of imitating, synchronising, and aligning movements in time between social partners may help to improve interpersonal motor synchronisation in autistic individuals, which has previously been associated with improved social outcomes (Behrends et al., 2012; Cirelli et al., 2014; Fitzpatrick et al., 2017; McNaughton and Redcay, 2020). It is observed that interpersonal synchronisation recruits brain areas that have previously been associated with social cognition and cognitive and emotional empathy; including the ventromedial prefrontal cortex and inferior parietal lobule (Koehne et al., 2016b). As such, synchrony during social interactions is related to cognitive empathy in non-autistic individuals, with research demonstrating that this mechanism might be attenuated, but not absent, in autistic individuals (Koehne et al., 2016b). Interestingly, increased synchrony with a social partner has been associated with symptom severity in terms of improved social functioning (McNaughton and Redcay, 2020). Further, dynamical measures of social motor synchronisation ability have been related to various measures of social competence that index ASD traits; providing initial support for a social motor synchrony model of autism (Fitzpatrick et al., 2017). Therefore, attending to an individual's ability to mirror and synchronise to another's actions provides a promising avenue to attenuate and improve social skills and communicative outcomes in autistic individuals (McNaughton and Redcay, 2020).

6.2. Rhythm

ASD may include profound challenges to neurological connectivity between and within various areas of the brain (Kana et al., 2014; Lidstone et al., 2021). For example, in comparison to typically developing age-matched controls, autistic children are observed to have significantly weaker connectivity between the amygdala and several brain regions, including the bilateral medial prefrontal cortex, temporal lobes, and striatum, which are involved in social communication and repetitive behaviours (Shen et al., 2016). Similarly, disruptions in the connectivity of the salience network and frontal cortex of children with an autism diagnosis have also been reported (Hoffmann et al., 2016; Margolis et al., 2019). Such disruptions could affect the typical rhythms of sensory and social connectivity, resulting in a cascade of confusing perceptual experiences that affect the finely-tuned 'choreography' of social interaction (Amos, 2013).

Condon (1975) investigated the role of self-synchrony and interactional synchrony in communication and social interaction, suggesting these processes may be impaired in children diagnosed with ASD due to delayed sound processing. For example, an autistic infant may appear distracted from their caregiver as their sensory world lacks pattern and focus due to mistiming; subsequently compromising crucial sharing of experiences and vital rhythmic interactions between infant and caregiver (Condon, 1975, 1979; Trevarthen, 2011).

Researchers, investigating audio-visual processing, have demonstrated that the binding window (the window of time in which inputs from various sensory stimuli occur in quick enough succession to ascribe them to a single event) was twice as long for autistic participants in comparison to a control group (600 ms vs. 300 ms; Foss-Feig et al., 2010). At a neurological level, this small difference in time can be sufficient to prevent or even inhibit multisensory experiences from blending into one single and coherent perception. Consequently, incoming sensory stimuli; such as, sight, sound and smell, will not couple as smoothly. Unrelated events may be perceived as connected, whilst related events may be acknowledged without the precise timing that informs meaning (Amos, 2013). As a result, this large binding window may burden social interactions with irrelevant and confusing associations in autistic individuals.

Attending to the feeling of rhythmicity and increasing knowledge of timing during DMT or physical activity could, therefore, have implications at a neurological level, helping to reduce the binding window and thus increasing the likelihood of coherent social perception. As a result, the use of rhythm may be extremely beneficial in enhancing the social-communication skills of autistic children (Morris et al., 2021).

7. Limitations and future directions

A multitude of studies show the great benefits of coordinated movement in typically developing individuals and research has

highlighted the potential of coordinated movement and physical activity as a therapeutic intervention for autistic children. Specifically, physical activity-based interventions tailored to increase opportunities for communication demonstrate enhanced social interactions and communication skills in autistic children; thus, alleviating an often functionally impairing trait of autism. Additionally, DMT, involving mirroring and rhythm, highlights the powerfulness of physical activity in the form of dance to enhance social-communicative skills in the autistic population.

Despite the advantageous outcomes observed from many of the studies involving coordinated movement, conclusions must be drawn whilst recognising some of the studies' limitations. For example, many of the studies discussed are limited by their small sample sizes, thus reducing their generalisability. Therefore, research should aim to test hypotheses that explore beneficial elements of physical activity and dance in clinically relevant sample sizes, whilst using reliable and tested outcome measures. Additionally, some of the studies discussed utilised a case-study design or pre- and post-intervention testing within samples. Whilst these studies are useful and allow for detailed and in-depth analysis of the participant and subsequent outcomes, they are difficult to draw definite conclusions from. It is not possible to successfully attribute the observed positive (or negative) outcomes solely to the intervention without the presence of a control or comparison group (Gerstein et al., 2019). Subsequently, more studies should strive to implement a control or comparison group into their study design; aiming to randomise matched participants to specific groups, subsequently limiting potential bias and improving the validity of the results observed.

Additionally, determining the most advantageous duration and frequency of coordinated movement interventions for autistic children is necessary. For example, are smaller, more frequent physical activity sessions more effective than longer, less frequent physical activity sessions? The studies discussed within this narrative review used coordinated movement-based interventions that spanned from less than 10 weeks to48 weeks. Therefore, determining the most advantageous duration of physical activity interventions may be beneficial and improve their integration into practice. Similarly, whilst DMT has already shown several positive effects utilising techniques such as mirroring and rhythm for autistic children, it is unknown if these techniques could be further enhanced. What is the optimum duration of DMT sessions for autistic children? What is the most beneficial group size - dyads or triads, during mirroring for children diagnosed with ASD? What is the most beneficial rhythm to use when working with autistic participants? Answering these research questions could substantially improve the benefits of DMT observed in this clinical population. Furthermore, many of the mirroring studies and DMT studies included mirroring between neurodiverse individuals and a trained neurotypical individual (Escalona et al., 2002; Field, 2017; Field et al., 2001; Morris et al., 2021). Future studies may wish to explore the effectiveness of child-to-child based mirroring or child-to-sibling based mirroring, instead of child-to-teacher or child-to-therapist mirroring to further enhance and improve imitation skills and social interaction between autistic children or with their families and investigate the most beneficial rhythm to use when working with autistic individuals.

Investigating the effects of combining these elements of DMT (mirroring and rhythm) into new sports/physical activity-based interventions could produce impressive therapeutic benefits on communication skills and social development for autistic children. From this, improved interventions could readily be implemented into practice at a relatively low cost or used in Special Education Schools during Physical Education (PE) classes. In addition, any schools or clubs that cater for autistic children could use such interventions during their PE lessons, activity breaks, or warm-ups as the intervention would exist in a physical activity capacity, whilst also helping to develop communications skills and increase social development.

From a clinical perspective, there is a requirement to explore methods used for increasing physical activity engagement in autistic children. Whilst the scientific literature suggests engaging in physical activity and coordinated movement elicits positive social outcomes, it is well recognised that there is a low rate of physical activity participation in children diagnosed with ASD (Healy and Garcia, 2019; Srinivasan et al., 2014). A previous study found that in a sample of 83 autistic children, only 12% were physically active (Memari et al., 2015). Most children were found to engage in solitary play rather than physical social activities. Furthermore, the rate of physical activity participation was closely associated with sociodemographic variables, such as gender and family income. A more recent study, which analysed the weekly physical activity, sedentary behaviour, and body mass index classification of 33,865 individuals (autism spectrum disorder, n = 1036) from the 2016–2017 National Survey of Children's Health (United States), revealed autistic children and adolescents engaged in less physical activity and were more likely to be overweight and obese compared to their typically developing peers (McCoy and Morgan, 2020). Such studies highlight the need to improve the accessibility of physical activities for autistic children; removing barriers and developing targeted programmes to increase participation rates of autistic children in physical activity.

Although we have attempted to delineate how coordinated movement may lead to improvements in social skills, more work is needed to understand the mechanisms that may produce such improvements (Lang et al., 2010). Investigating the mechanistic processes that result in positive outcomes could further assist practitioners in the development of more efficient and effective programs targeting communication challenges in autisitc children. Further, understanding the key elements of physical activity and the biological or physical mechanisms that elicit positive and sustained outcomes could help integrate these approaches into practice. Therapists, teachers, sports leaders, and coaches might then draw on these elements to further support the social skills of autistic children during therapy sessions, physical education classes, sports groups, or team games, subsequently aiding autistic individuals to more effectively integrate into a team.

8. Conclusion

In conclusion, coordinated movement appears to offer substantial therapeutic benefits for autistic children. Physical activity and coordinated movement have been shown to enhance communication skills and social development, which may potentially improve QoL in autistic children. Importantly, mirroring and rhythm stand out as two key factors of coordinated movement in DMT that may elicit positive changes in social skills. Future research should endeavour to improve sample sizes in which studies are carried out and explore mechanistically how physical activity leads to improvements in communication skills and social development. As a result, coordinated movement-based interventions could be more readily recommended and implemented into social and clinical practice.

CRediT authorship contribution statement

Phoebe Morris: Conceptualization, Investigation, Writing – original draft. **Edward Hope:** Writing – review & editing. **Tom Foulsham:** Writing – review & editing. **John P. Mills:** Writing – review & editing, Supervision.

Declaration of competing interest

None.

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